WINFLEX for WINDOWS 95

A Mechanistic-Empirical Overlay Design System for Flexible Pavements

RP 121-II

User's Guide and Tutorial Examples

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Table of Contents

Chapter 1

Introduction

WINFLEX is a program developed for Windows 95. It is designed for engineers who use the mechanistic-empirical pavement design procedures. This manual will guide you through all the features of the program, including over 30 WINFLEX commands. The program can be used by pavement design engineers who have minimum knowledge about the use of a personal computer running under the Windows operating system. It includes special features that link to other Windows applications.

Background

The WINFLEX computer program is a mechanistic-based overlay design system for flexible pavement. The mechanistic-based concept is not new to pavement design engineers and has been addressed in several publications. It is not our intention to discuss or review the conceptual development in this manual. The reader is referred to References 1-4 listed in Appendix A for details on the mechanistic-based concept in general and the program documentation in particular. It is worthy to mention that the development of this computer program was done over a three-year period under two contracts between the University of Idaho National Center for Advanced Transportation Technology (NCATT) and the Idaho Transportation Department (ITD). The first contract (Research Project RP 121, Agreement No. 95-60) dealt with the system development and its implementation in a computer software. The software developed was DOS based due to the fact that Fortran computer language was only available in the DOS environment. That program was named FLEXOLAY. It was developed using two computer languages: Fortran 77 and Visual Basic for DOS. Later in 1996, Microsoft released the Fortran Power Station 4.0 for Windows 95, which is a 32-bit Fortran Compiler. Shortly after the release of the new Fortran compiler, ITD requested an upgrade of the FLEXOLAY program to operate under Windows 95. A second contract was initiated between NCATT and ITD (RP 121 Phase 2, Agreement No. 97-44) and the result was this software in hand, WINFLEX. Thus, WINFLEX is the Windows version of the FLEXOLAY overlay design program. The upgrade was not only in the transfer to a new computer environment, but also in the design features of the program. For example, FLEXOLAY could only design an overlay for a single pavement section, while WINFLEX can design for multiple pavement sections at once. This feature greatly facilitated the automation of the overlay design process for each milepost along the entire road length. Enhancements were also made to the output printing and storage. An export feature was added in order to export the output to other Windows applications such as MS Word, Excel and Notepad. In summary, WINFLEX is a versatile overlay design software that runs under Windows 95. It is based on mechanistic-empirical analysis of pavement sections and incorporates the effect of seasonal variation on the pavement layers' properties.

About WINFLEX for Windows 95

WINFLEX contains two main codes using two computer languages: Visual Basic 4.0 and Fortran Power Station 4.0 (Fortran 90). Both codes run under the Windows 95 operating system. The Visual Basic code, which is mainly for the user interface, handles the data input and output system. The input data are stored in a file named PAVE.DAT. This file is created by the Visual Basic code to be used by the Fortran code in the program. The Fortran code reads all input data from the PAVE.DAT file and performs all the mathematical computations for the pavement overlay design. The overlay design results are sent back to the Visual Basic code for screen display, storage, printing, or exporting to other applications. The Fortran code is compiled as a Dynamic-Link Library (DLL). A Dynamic-Link Library is an executable file, but is usually used as a library for Windows applications. A .DLL contains one or more functions that are compiled, linked, and stored separately from the applications using them. In WINFLEX, the Fortran 90 code is referred to as SYSANDLL2.DLL as opposed to the Fortran 77 code in FLEXOLAY, which was referred to as SYSAN.EXE. The advantages of using a .DLL over .EXE files include:

- The functions in the .DLL can be changed without recompiling or re-linking the Fortran code to the Visual Basic, as long as the functions' arguments and return types do not change. This allows easier upgrading of WINFLEX. For example, new response models, material characterization, or failure criteria can be added or modified in the future. This is likely expected, especially when the new SHRP Superpave mix design system is fully implemented.
- Programs written in different languages can call the same .DLL functions, as long as each program follows the functions' calling conventions. To ease the calling convention even further, and follow

the same tradition in FLEXOLAY, the .DLL developed in WINFLEX (SYSANDLL2.DLL) was compiled in a way that no calling arguments are expected. It reads the data file PAVE.DAT created by the Visual Basic interface.

- Multiple applications can access the same .DLL. This reduces the overall amount of memory needed in the system, which results in fewer memory swaps to disk and improves performance.
- WINFLEX now has a smaller executable file.

Apart from the advantages of using the new Fortran code, the new Visual Basic code provides for the following:

- Linking with all Microsoft applications, including Excel, Word, and Access software.
- Better enhancement of the interface.

In addition to the technical advantages listed above, all applications in the market now are heading towards a 32-bit environment, whether Microsoft or not, engineering related or not. The use of 32-bit applications is now a reality; therefore, it was essential to upgrade the FLEXOLAY program.

About This Manual

The objective of this manual is to give a brief introduction to the program and to facilitate its use. It provides tutorial examples as well to help understand the use of the program for a single-location design case and a multiple-location design case.

The manual contains three chapters and four appendices.

- Chapter 1: **Introduction** provides a brief background on WINFLEX. Setup, system requirements, and design features are also explained
- Chapter 2: **Program Operation** walks you through the different screens in the program and explains how the input data file is created.
- Chapter 3: **Tutorial Examples** goes though two examples: one for running a single-location design and another for a multiple-location design.

The four appendices are:

- **Appendix A**: List of references for further reading on the program documentation.
- **Appendix B**: Examples of the input and output files.
- **Appendix C**: Flowcharts that document the program development.
- **Appendix D**: How to get more help.

System Requirements

To use WINFLEX the user needs:

- The master WINFLEX disks.
- An Industry Standard Architecture (ISA) computer, such as an IBM PC/AT or compatible, or a Micro Channel Architecture (MCA) computer, such as an IBM Personal System/2 or compatible running under a Windows 95 or NT operating system.
- A graphics card compatible with Microsoft Windows 95 or later.
- A minimum of 2 megabytes (MB)of random-access memory (RAM).
- Hard disk with 20 MB available space.
- Microsoft Excel is an option needed for advanced features in WINFLEX, such as exporting a design summary table to Excel's worksheet.

Installation

The WINFLEX Setup program decompresses and copies the WINFLEX program and other files to the hard disk of the PC running Windows 95 or to the hard disk of the PC in a network running Windows NT, Version 4 or higher. The program must be installed using the WINFLEX Setup program file. Files can not be simply copied to the hard disk. The following instructions explain how to install WINFLEX on the hard disk.

1. Insert the disk labeled Disk 1: SETUP in the floppy drive, e.g., drive A.
2. Click the Start button on the desktop and go to the Run command.
3. At the command line type **a:setup** and press Enter.
4. Follow the Setup instructions on the screen.
5. You will be prompted for the directory where you want to install WINFLEX. (Note that only WINFLEX files will be installed in that directory, the rest of the required system files will be installed in their appropriate locations.)
6. Since WINFLEX is like any Windows 95 applications, it uses some of the system files. You might be prompted that a certain file already exists and "Do you want to replace it?" Although it will not affect the program nor your computer, it is advised to press the No button.

Note that the program can be installed on another drive where 20 MB is available. For example, it can be installed on a Zip disk. In such case, refer to the correct drive name. That is, letter E, which refers to a Zip drive, may be used in place of C, which refers to a hard disk.

WINFLEX Features

The concept adopted in the development of this overlay design program is based on mechanistic analysis of the multi-layer flexible pavement elastic system. This elastic analysis requires the mechanical properties of the pavement layers at each season of the year. Elastic properties required are represented by the elastic moduli and the Poisson's ratios of the pavement layers. Elastic moduli of existing pavement layers are usually determined by non-destructive testing, such as the Falling Weight Deflectometer (FWD). Deflection data measured by a FWD is used in backcalculation software to estimate the layers' moduli values. In WINFLEX, a damage analysis is conducted to assess the remaining life of the existing pavement using fatigue and rutting failure criteria. By considering the total damage that occurred in the pavement due to either rutting or fatigue, an overlay thickness is determined to resist future traffic. The reader is advised to refer to references 1 and 4 in Appendix A for details on the program development. Following are brief descriptions of the new features added in the WINFLEX program over that of FLEXOLAY:

Fatigue and Rutting Models

This program provides the user with the ability to choose from nine different fatigue models and six different rutting models used by several agencies around the world. This feature can also be used by engineers to decide which model is most suitable for their local pavement conditions.

Adjustable Shift Factors

Shift factors account for the construction variability, differences between laboratory and actual (field) state of stress, and other unknown factors. WINFLEX allows the user to control the fatigue shift factor for both old and new asphalt layers.

Temperature Correction

Asphalt mixture modulus of elasticity depends on temperature and time of loading. At high temperatures, asphalt acts like viscous liquids. At low temperatures, it behaves like elastic solids. WINFLEX adjusts the asphalt modulus for temperature in each of the four seasons: winter, spring, summer, and fall. In addition, different asphalt cements behave differently with temperature. WINFLEX can adjust the modulus of elasticity based on a user input modulus versus temperature curve for the asphalt mix under consideration. The program uses simple curve-fitting techniques to find the modulus corresponding to the input design temperature.

Environmental Factors

The main factors that affect the change of material properties are moisture variation (for unbound layers) and temperature (for bituminous treated layers). The state of Idaho is divided into six pavement climate zones, which are based on six geographic areas (Reference 5). Each has approximately equal climate parameters, such as annual air temperature and precipitation, and equal climate indices, such as Thornthwaite Moisture Index (TMI) and Freezing Index (FI). The climate zones and their characteristics are used to determine the magnitude of the expected moisture changes for the various soil groups as a function of location, and to define the duration and onset dates of the possible operating periods. WINFLEX contains these climatic parameters as default values for each of the six regions. For pavement conditions outside Idaho, or if the user wants to overpass the given default values, WINFLEX provides the flexibility to enter other parameters as specified by the user.

Multiple-Location Design Feature

In some cases, the user may select to determine an overlay thickness for each milepost where moduli values are determined by FWD backcalculation procedures. To do this one at a time is a tedious and time-consuming process, especially if the pavement section is long and contains a number of milepost test sections. In WINFLEX, a new feature was added where this process is automated. The designer will input only one general file for the common parameters and the specific properties of the pavement layers at each milepost are called from a data file generated directly from the backcalculation software, MODULUS, which is discussed in Chapter 2. The data file needed from the MODULUS output is referred to as an .ETF file. The .ETF file contains the elastic moduli, E, and the testing temperature, T, at each milepost. Details on the use of this feature and how to create an .ETF file are explained later in this manual.

Chapter 2

Program Operation

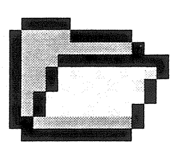
In this chapter, you will learn how to start the program and use it for both single- and multiple-milepost design. When designing for one milepost at a time, you should refer to the single-milepost design. WINFLEX also has a multiple-milepost feature where you can design multiple sections in one run.

Starting WINFLEX

To run WINFLEX, go to the installation directory you chose during the Setup and double click on WINFLEX.EXE to run the program. If you chose the default directory during the Setup, you can run WINFLEX from the Start-Programs menu of Windows 95, located at the bottom-left corner of your screen.

When you first start WINFLEX, you will see the opening screen shown in Figure 1. Once you move the mouse, this screen will disappear and you will see the screen showing the Main menu (Figure 2).

You can either start a new design by either clicking on the New icon on the far left of the upper status bar or from the File menu. Or, if you had previously entered your data and saved it in the input data file (.INP), you can load those inputs by choosing the Open icon on the upper status bar or the Open command from the File menu. The Open icon is shown in the left margin of this page. Once you open a saved file, all the input screens will be loaded with the saved data .



Open icon on the upper status bar

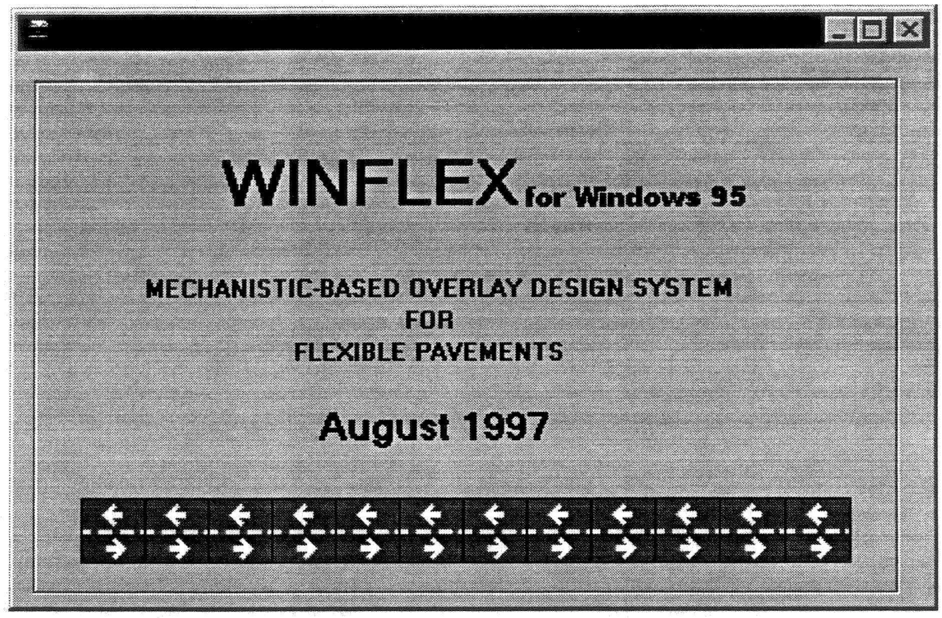


Figure 1. Opening Screen

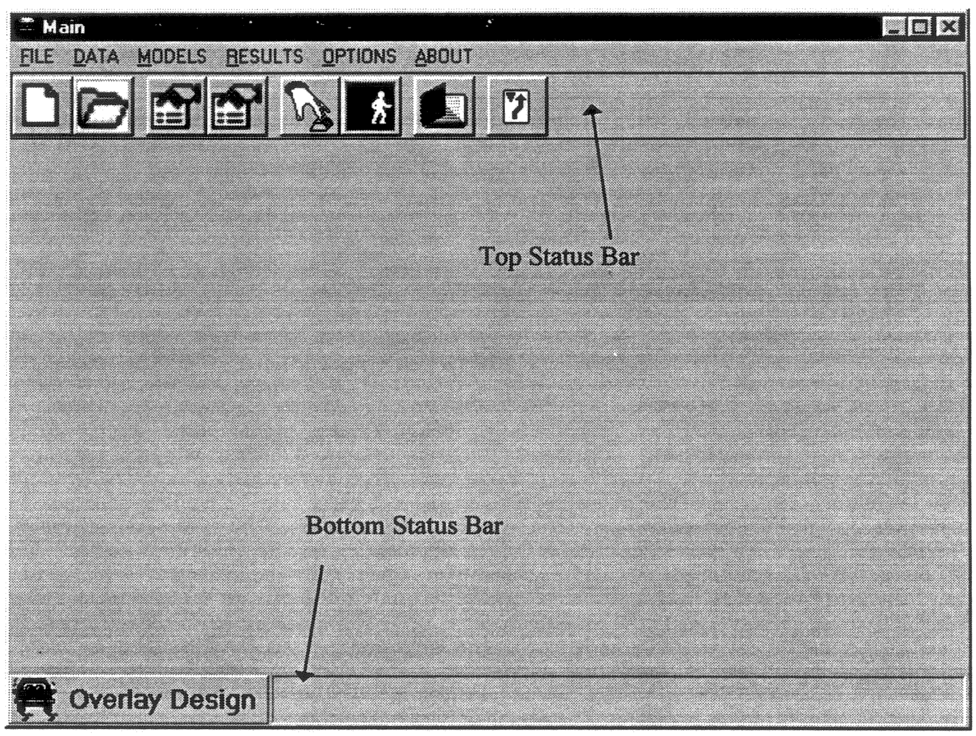


Figure 2. Main Menu

Entering Input Data

The screen shown in Figure 3 will appear asking you to choose the type of run: single location or multiple locations.

If you click on the single location option and then the OK button, you will start entering the required data for your design. WINFLEX is set up to walk you through the input screens and segregating related groups of data in different screens.

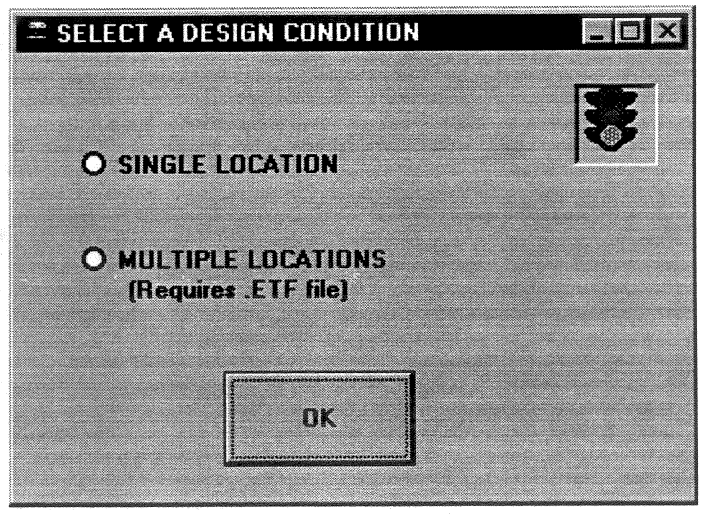


Figure 3. Design Condition

If you are running a multiple-location design, you will need to prepare a file containing the test temperature, the layer moduli, and the layer thickness for each location (.ETF extension) before starting WINFLEX. This file will be referred to as the .ETF file. It can be prepared using any word processor or spreadsheet and saved as a text file with the .ETF extension, as explained later in this chapter. The .ETF extension will make it easier for you to sort and locate your files, but any extension will work if the text in the file follows the format given below. After you have prepared the .ETF file, you can start WINFLEX. In the Design Condition screen, choose the Multiple Location option.

Note that you will not be able to input the moduli and the thickness of the different layers; they will have an N/A, signifying that they will be read from the .ETF file. Also you will not be able to enter the test temperature.

Once you click on the Run Multiple-Location option, you will be prompted to the name of the .ETF file and the screen shown in Figure 4 will appear. Choose the .ETF file you wish to run with the rest of your input data and click Open. WINFLEX will then start designing your locations. After the program finishes running you will be asked to save the results in a file (Figure 5). Type in the filename and click Save. If you do not wish to save it, just click Cancel. The saved file uses the extension .FLX by default.

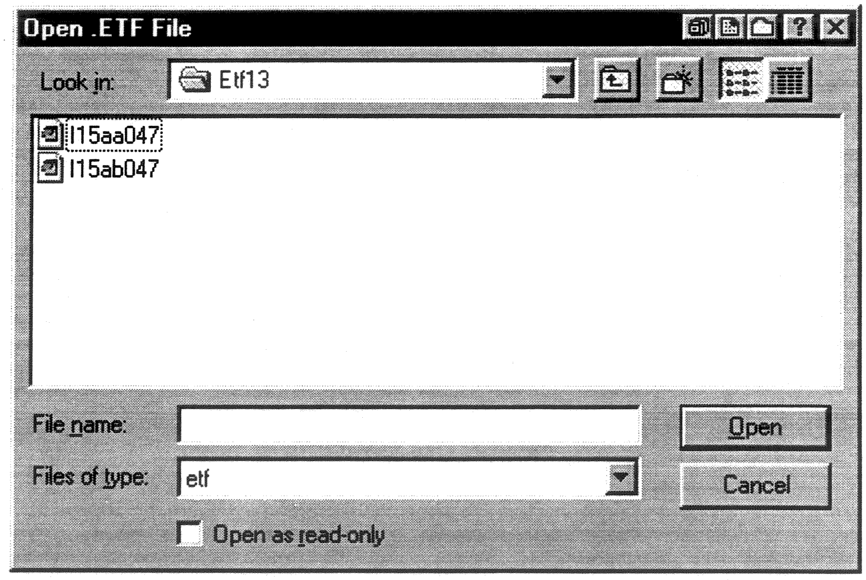


Figure 4. Open .ETF File Screen

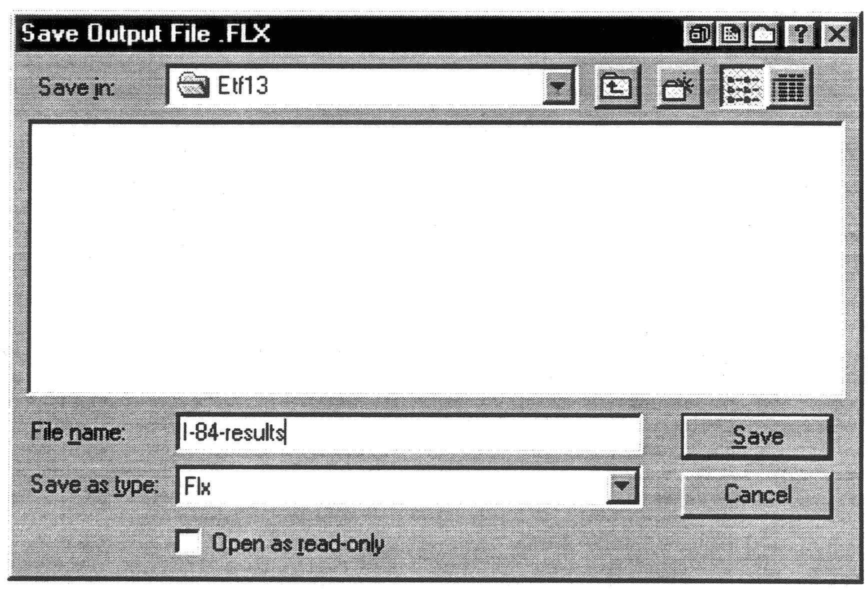


Figure 5. Save Output

Pavement Data

The first required input is the pavement-related data shown in the Pavement Data screen (Figure 6).

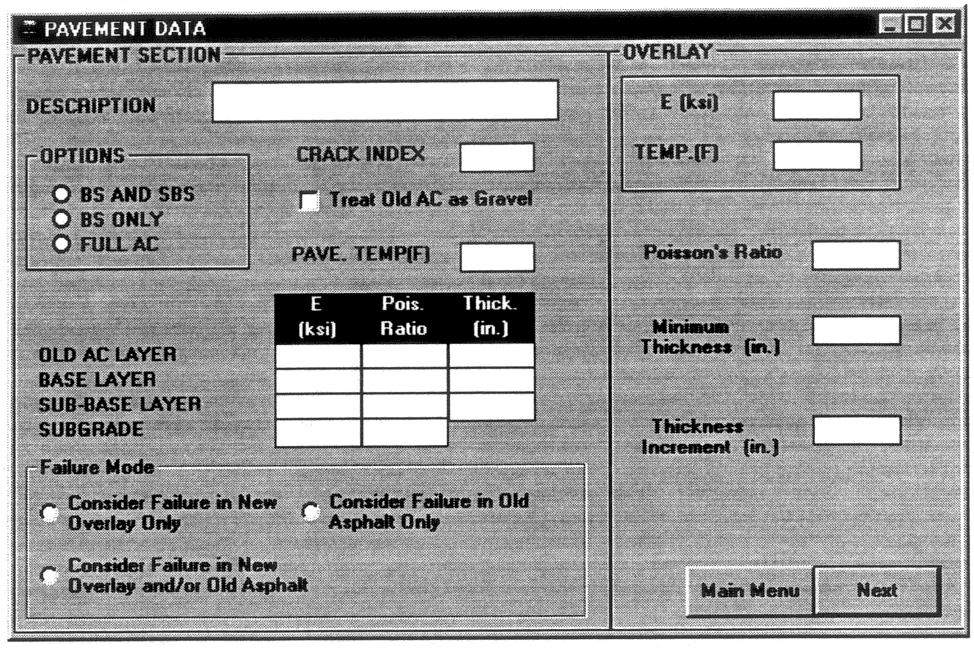


Figure 6. Pavement Data

Listed below are the explanations of input data required in this screen.

For the existing pavement section:

- Description: Here you can enter as many characters as you want to describe the design you are doing. It will be saved with the data you enter as an identification if you later decide to use the same data.
- Crack Index: This value should be in accordance to the Idaho Transportation Department pavement evaluation system (does not affect overlay calculations).
- Treat Old AC as Gravel: If this box is checked, the program will treat the old asphalt as a gravel layer.
- PAVE. TEMP. (F): Pavement temperature during FWD test in °F.
- Check one only in the Options block:
    - ⇒ BS AND SBS option: If the existing pavement section includes base and subbase.
    - ⇒ BS ONLY option: If the existing pavement section includes base only.
    - ⇒ FULL AC option: If the existing pavement section is full-depth asphalt.

Existing layer properties:

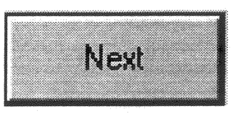
- E (ksi): Is the modulus of the layer in ksi. Moduli values are obtained by backcalculation of deflection data measured by Falling Weight Deflectometer. Programs such as MODULUS (Reference 6) can be used for backcalculation.
- POIS. RATIO: Is the Poisson's ratio of the layer.

- THICK. (in): Is the thickness of the layer in inches.

For the overlay:
- E(ksi): Is the overlay elastic modulus.
- TEMP. (F): Is the reference temperature at which the overlay elastic modulus value was determined.
- Minimum Thickness (in): Is the minimum overlay thickness required in inches.
- Thickness Increment (in): Is the overlay thickness increment in inches.
- Failure Mode: Is the type of failure, whether in old asphalt, new overlay, or both.

The screen changes as the selected option changes (i.e., changing the option between BS AND SBS, BS ONLY, and FULL AC). The base layer and the subbase layer disappear when FULL AC is selected. The subbase layer disappears when BS ONLY is selected. The data can be entered after moving the mouse pointer to the data boxes provided and pressing the mouse button. Also, the Tab key can be used to move between the data boxes, and the arrow keys can be used to move between the options.

Soil Parameters



After you have entered the pavement data, then click the Next button in the bottom left corner of the screen to move to the Soil Parameters screen. The screen layout depends on the option selected in the pavement screen. The shape of the full screen is shown in Figure 7. When the pavement section includes the base only, the subbase option will disappear. When the pavement section is full-depth asphalt, the base and the subbase options will disappear.

The base options are:
- GRANULAR option: Means that the layer is granular and stress dependent. When this option is selected, the parameters K1 and K2 will appear. These are stress dependency factors.
- GRAN.[LINEAR] option: Means that the layer is granular and considered stress independent. When this option is selected, the parameters K1 and K2 will disappear.
- CEMENT T. B. option: Means it's a cement treated base. When this option is selected, the parameters K1 and K2 will disappear.
- BITUMEN T. B. option: Means it's a bitumen treated base. When this option is selected, the parameters Vb and Va will appear instead of K1 and K2. Vb is the volumetric percentage bitumen, and Va is the percentage air volume in the bituminous treated base mix.

The subbase options are:

- GRANULAR option: Means that the layer is granular and stress dependent. When this option is selected, the parameters K1 and K2 will appear. These are stress dependency factors.
- GRAN.[LINEAR] option: Means that the layer is granular and considered stress independent. When this option is selected, the parameters K1 and K2 will disappear.

The subgrade options are:

- FINE option: Means that the subgrade is fine grained and stress dependent. When this option is selected the parameters K1-F and K2-F will appear. These are stress dependency factors for the fine material.
- GRANULAR option: Means that the layer is granular and stress dependent. When this option is selected, the parameters K1-G and K2-G will appear. These are stress dependency factors for the coarse material.
- LINEAR option: Means that the subgrade is considered stress independent. When this option is selected, the parameters K1 and K2 will disappear.

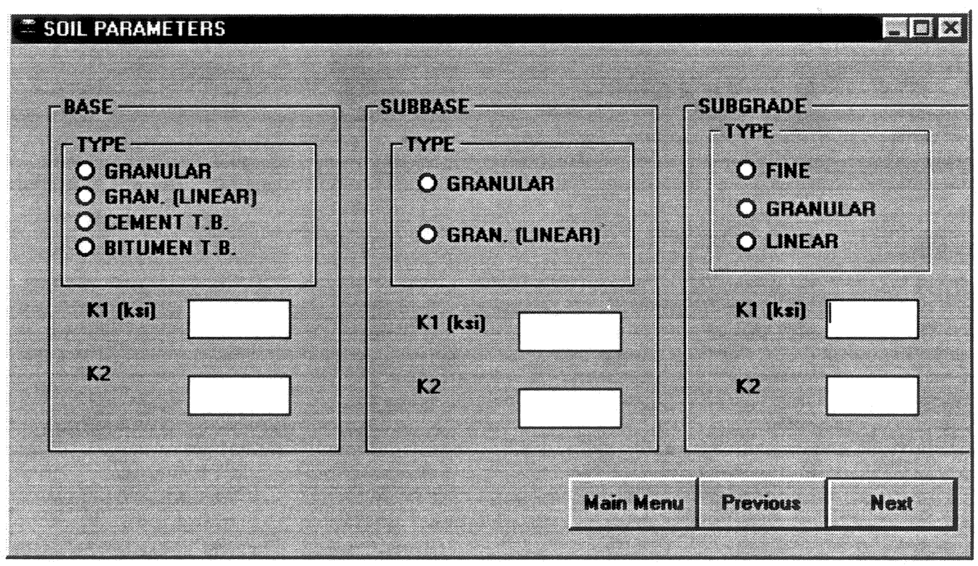
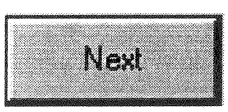


Figure 7. Soil Parameters Screen

General Data



Again, you will move to the following set of inputs by clicking the Next button at the bottom right corner of the screen. The General Data screen will appear (Figure 8).

For the vehicle load properties:

- DUAL TIRE LOAD in lb (default is 4500 lbs.).
- DUAL TIRE SPACING in inches (default is 13.2in).

- TIRE PRESSURE in psi (default is 80 psi).

For traffic:

- INCLD. PAST TRAFFIC check box: When not checked, the past traffic label and the corresponding data box will disappear.
- ESTIMATED FUTURE: Is the estimated future traffic repetitions in terms of equivalent single-axle load (18kips ESAL) for the design period.
- PAST ESAL: Is past traffic repetitions in (18kips ESAL) terms of equivalent single-axle load units.
- FATIGUE SHIFT FACTORS: Here you can enter the shift factors for both the old asphalt layer and the new overlay that best suit your conditions.

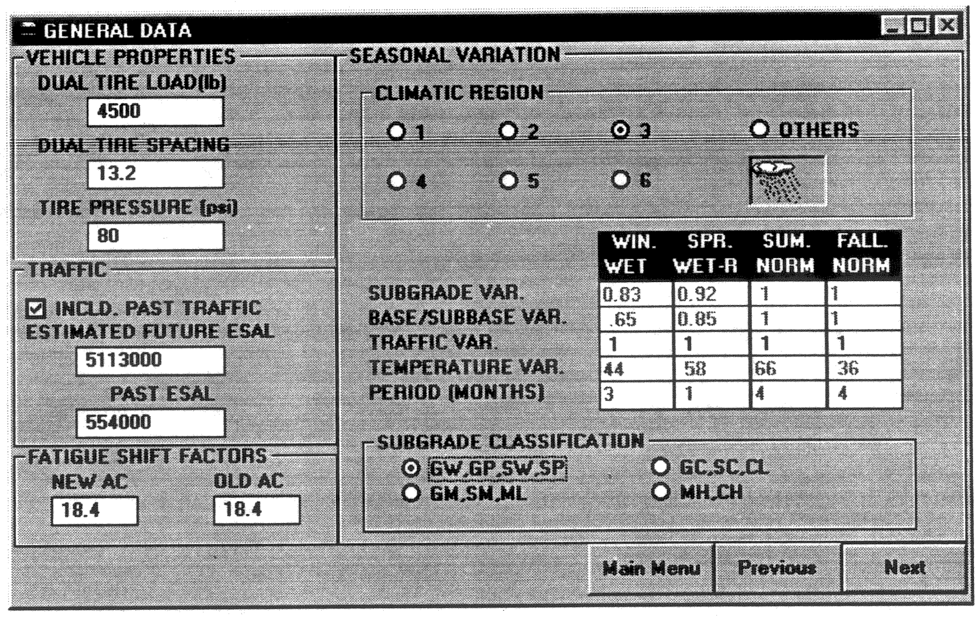


Figure 8. General Data

For seasonal variations:

- CLIMATIC REGION option: Check one of the six climatic zones in Idaho or provide your own seasonal factors by checking on the OTHERS option.
- SUBGRADE VAR.: Is the seasonal factor for subgrade modulus adjustment.
- BASE/SUBBASE VAR.: Is the seasonal factor for base/subbase modulus adjustment. (Will be disabled for full-depth asphalt pavement section.)
- TRAFFIC VAR.: Is the seasonal factor for variations in traffic.
- TEMPERATURE VAR: Is the representative seasonal mean air temperature.
- PERIOD (MONTHS): Is the period of each season in months.

SUBGRADE CLASSIFICATION options: Is the subgrade classification according to the Unified Soil Classification system. These options only appear when ZONE 3 or ZONE 6 is selected.

For ZONE 1 to 6, the SUBGRADE VAR., BASE/SUBBASE VAR., TEMPERATURE VAR., and PERIOD values are loaded automatically by the program and the user can not change these values. In order to change the values, the ZONE has to be selected as OTHERS.

The SUBGRADE VAR. values depend on the subgrade modulus value entered in the Pavement Data screen and will change by changing the modulus.

Selecting Failure Models

If you click the Next button, a screen showing the fatigue and rutting equations that you can use in your design will appear (Figure 9). This feature is disabled unless needed for research purposes. The default fatigue and rutting failure models are those of the Asphalt Institute.

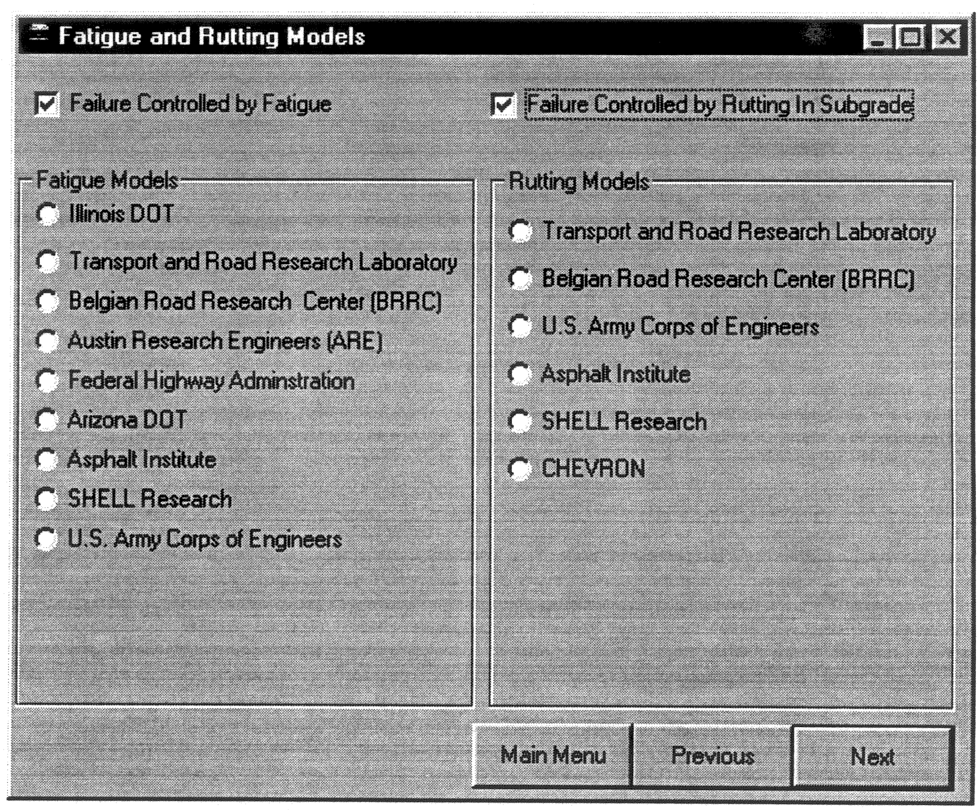
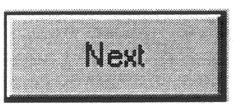


Figure 9. Fatigue and Rutting Models

The fatigue models used are (References 1 and 2 contain more details on these models):

Illinois Department of Transportation,
Transportation Road Research Laboratory,
Belgian Road Research,
Austin Research,
Federal Highway Administration,
Arizona Department of Transportation,
Asphalt Institute (used by Idaho DOT),
Shell Research, and
U.S. Army Corps of Engineers.

The rutting models used are (References 1 and 2 contain more details on these models):
Transportation Road Research Laboratory,
Belgian Road Research,
U.S. Army Corps of Engineers,
Asphalt Institute,
SHELL Research, and
CHEVRON.



By choosing the controlling pavement failure mode and the corresponding model, you have completed the input for the single-location design case. By clicking the Next button, you will return to the Main menu.

Temperature Correction

One optional input is the asphalt modulus temperature correction curve. If you are using non-conventional asphalt, you can enter the modulus-temperature curve for the asphalt temperature correction. This is optional, since WINFLEX already has a modified SHRP equation. You can access this screen from the OPTIONS menu in the Main menu bar (see Figure 2). The layout of this screen is shown in Figure 10.

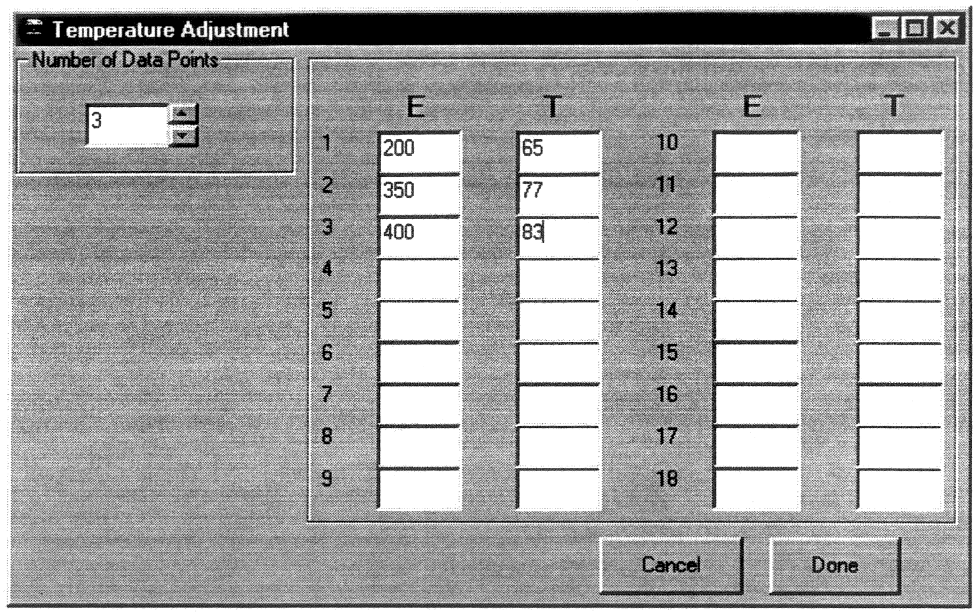
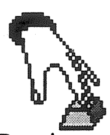


Figure 10. Asphalt Temperature Correction Screen

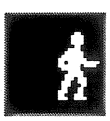
First, enter the number of data points that you have available by either typing in the number or by scrolling the arrows shown in the Number of Data Points box in Figure 10. Then, enter the modulus value and the corresponding temperature for the number of data points you have. A minimum of three and a maximum of eighteen data points are required.



The Run icon shown on the upper status bar.

Running the Program

To run a single-location design case, you can either go to the Results menu in the Main menu bar and choose the Run command or click on the Run Single Location icon on the upper status bar (shown in the left margin). The program will start running and the Results screen will appear after the program has finished the calculations (Figure 11). To run a multiple-location design case, you should choose the Run Multiple Location icon on the upper status bar (shown on the left margin) or the RunFile command from the Results menu.



Run Multiple Location icon shown on the upper status bar

Output and Results

The Results screen for the single-location design contains the required overlay thickness, plus a summary of the damage ratios for the different layers. If you click the Print button, a detailed output of the input values and the results will be sent to the printer. You can change printer setup by clicking the Printer Setup button.

To return to the Main menu or to hide this screen, click the OK button.

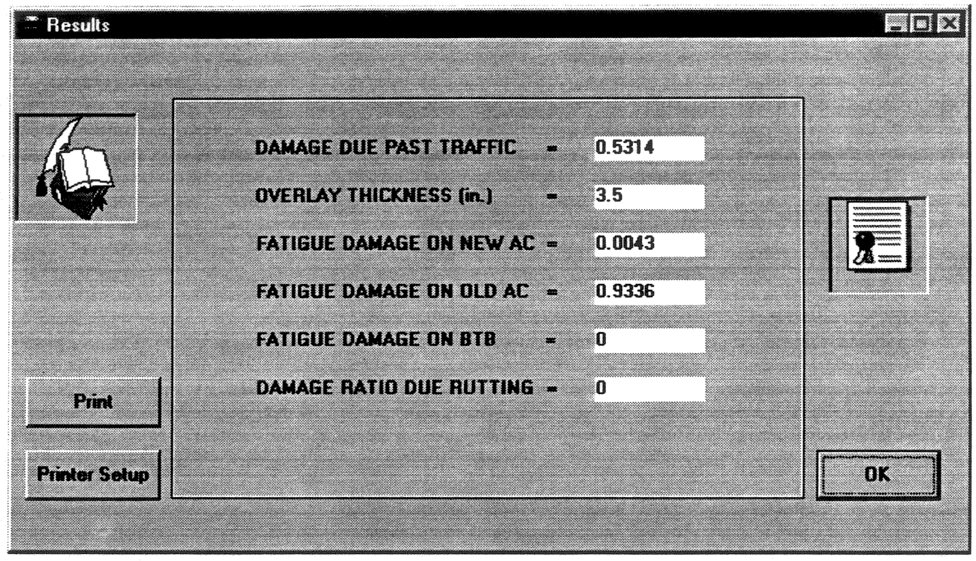


Figure 11. Results Screen

For the multiple-location design, after you are done with running and saving your results, you will be able to view them in a spreadsheet (Microsoft Excel). The screen shown in Figure 12 will appear and you can choose if you want to run another problem, view the Excel summary, or exit WINFLEX. If you choose to view the summary of the results, Microsoft Excel will start with a spreadsheet containing the mileposts and the corresponding overlay thickness and moduli values. When you exit Excel, you will return to the Convert to Excel screen (Figure 12).

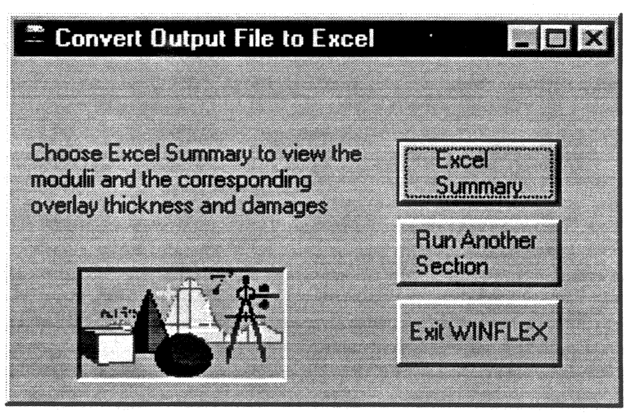


Figure 12. Excel Summary Option Screen

Before you exit WINFLEX, you will be prompted to save your input file (Figure 13). If you wish to save your input data for further use, click on Save. All your input data will then be stored in a file with an extension .INP.

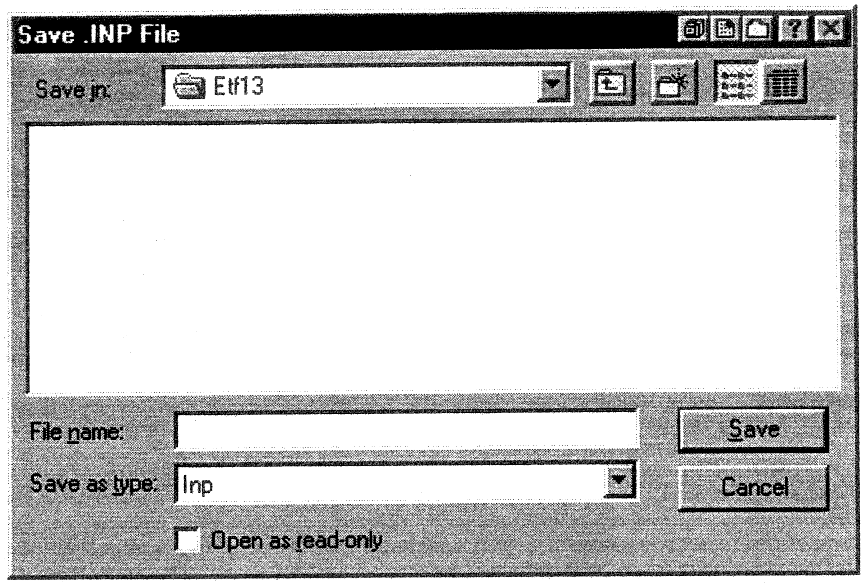


Figure 13. Saving Input Data

Guidelines for Preparing the .ETF File

An example of an .ETF file is provided in Appendix B. As shown, the first row in the .ETF file should include two inputs. In the first column, enter the number of layers for your design, excluding the new overlay. In the second column, enter a header for this file in order to make it easy for the user to identify the file. After this, each row represents a data set for a milepost. A single data set is provided in the following columns:

Column 1: pavement testing temperature
Column 2: milepost
Columns 3-6: Modului values for the existing pavement layers (in ksi)
Columns 7-9: layer thickness

Note that if the exiting pavement is full depth (i.e., only one layer over the subgrade), the user needs to enter only two E values (surface and subgrade) in column 3 and 4, and one thickness value in column 7 (asphalt layer). If two layers exist on top of the subgrade, three E values (surface, base, and subgrade) and two thickness values will be needed, and so on.

The Idaho Transportation Department has prepared a program to create the .ETF file directly from the modulus backcalculated program output, (You can contact the Idaho Transportation Departement's Materials Section in Boise, Idaho for a copy.)

There are three ways to prepare the .ETF file:

1. Using Microsoft Notepad:

    - On the first line, type the number of layers and a sentence to identify your file, separated by a space or a tab.
    - On the following line, type the test temperature, station, layer moduli values, and the layer thickness values with a space or a tab between any two values.
    - Go to the Save Dialogue and choose All Files (or *.*) for the file type. Type in the filename with the extension .ETF, for example, "EXAMPLE.ETF". Note that the quotation marks have to be used (Figure 14).

2. Using Microsoft Word:

    - On the first line, type the number of layers and a sentence to identify your file separated by a space or a tab.
    - On the following line, type the test temperature, station, layer moduli values, and the layer thickness values with a space or a tab between any two values.
    - Go to the Save Dialogue and choose Text Only for the file type. Type in the filename with the extension .ETF, for example, "EXAMPLE.ETF". Note that the quotation marks have to be used (Figure 14).

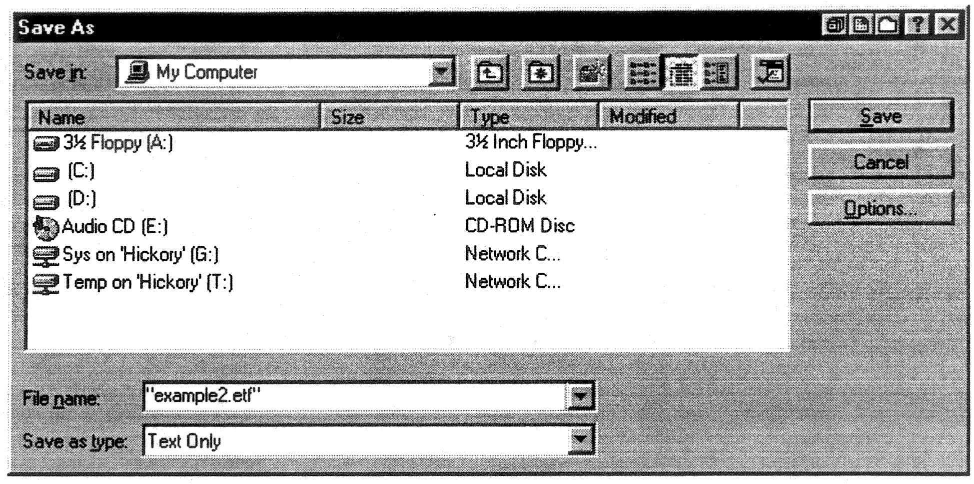


Figure 14. Saving the .ETF File Using Microsoft Applications

3. Using Microsoft Excel:

   - In the first cell (A1), type the number of layers. In the second cell on the first row (B1), type a sentence to identify your file.
   - On row 2, type the test temperature, station, layer moduli values, and the layer thickness values each in a separate cell starting at cell A2, and go across.
   - Go to the Save Dialogue and choose Text Only for the file type. Type in the filename with the extension .ETF, for example, "EXAMPLE.ETF". Note that the quotation marks have to be used (Figure 14).

Chapter 3

Tutorial Examples

This chapter includes examples of the two design cases incorporated in WINFLEX: single- and multiple-location cases.

Example 1: Single-Location Design Case

As explained in Chapter 2, a single-location or a single-milepost design case means that only one set of elastic moduli values is inputted into WINFLEX, and that there is only one overlay thickness to be calculated. The one set of moduli values of the pavement layers can be for a selected milepost, the average, the 75th percentile, or the 90th percentile of the moduli values of the pavement section. For example, if a pavement section where, let us say, FWD testing was made at 15 locations (mileposts), the designer may select one location that he or she considers to be representative. But this is usually not valid, and the designer should choose a set of moduli values for the pavement layers that represent the entire section. For that, statistical analysis of the moduli values should be made to determine the average, or any other statistically representative set of data. Idaho Transportation Department uses the 90th percentile. The bottom line is that only one set of moduli values is needed for WINFLEX to run a single-location design case.

In this example, the pavement section selected is located on Idaho's SH 95 from milepost 388.4 to 391.0, which means it is located in climate Zone 6. The pavement cross-section consists of 3.6 inches of plant mix asphalt concrete surface, 8.4 inches of untreated aggregate base, and 18 inches of crushed aggregate subbase. The subgrade is classified as silty gravel (GM-ML on the Unified Classification System). This pavement section was constructed in 1961 and the condition survey showed that the section has a crack index between 2 and 3.5, and a roughness index between 2.3 and 2.7, which implies poor serviceability and that the section requires rehabilitation. For overlay design, the traffic analysis revealed that the estimated past 18-kip ESALs is 554,000 and the estimated 18-kip ESALs for the next 20 years, starting from the date of the FWD test, is 5,113,000.

FWD testing was made to assess the structural capacity of the existing pavement along the entire length. Plant mix used to build the overlay has an average elastic modulus value of 350 ksi at 77°F. The following steps explain how to analyze the FWD data and how to use WINFLEX to design the overlay thickness for the entire pavement section.

Step 1: Backcalculation

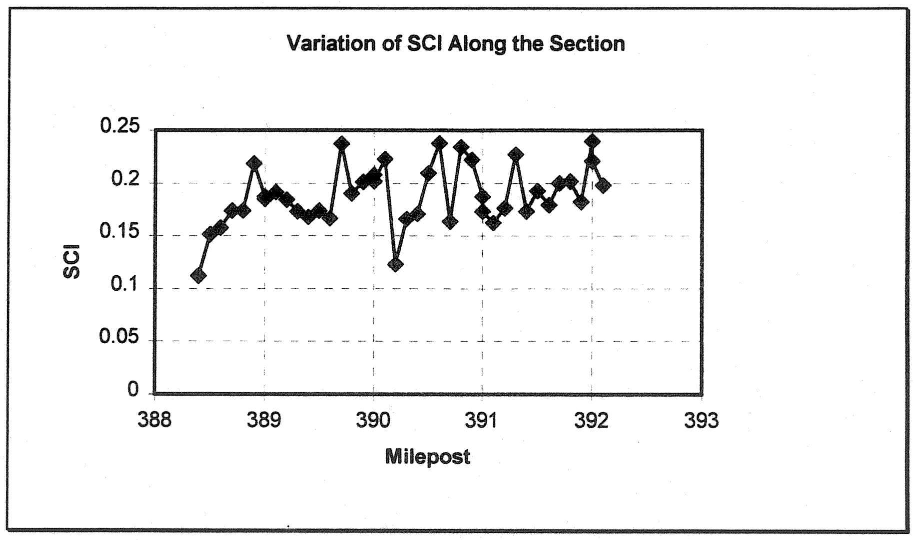


Figure 15. Variation of Surface Curvature Index

First, we need to analyze the FWD data to determine a representative set of moduli values for the existing pavement. For this purpose, the MODULUS backcalculation program was used to backcalculate the moduli values from deflections at each milepost. This process can be overwhelming. The reader is referred to the MODULUS manual (Reference 6) for details on how to use the program. The MODULUS program takes the FWD data as an input (.FWD file) and prints the output moduli values into a file with an extension .OUT; we will refer to it as the .OUT file. An example of the first run using MODULUS to analyze the pavement section in this example is shown in Figure 15. After converting the .FWD file to the .OUT file, the Surface Curvature Index (SCI) is calculated and plotted versus the milepost (Figure 15). A high SCI indicates a cracked, weak pavement and a low SCI indicates a strong pavement with no cracks at that location. However, the SCI indicates the weakness or strength in a relative sense and no objective determination of the actual modulus can be made from the SCI. The plot in Figure 15 indicates that the section is uniform to some extent.

Note that the MODULUS program uses an iterative method for backcalculation of moduli values from deflection data, therefore, it requires you to input a range for the layer moduli values. The backcalculation procedure is highly sensitive to the moduli range input, hence, MODULUS should be run many times, changing the input moduli range each time until it converges to reliable backcalculated values. For this example, the program was run 23 times. The output of the final run (23rd) is shown in Figure 16. More reasonable results were obtained in the final run (Figure 17).

MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)													Poisson Ratio Values	
District:	1								MODULI RANGE(psi)					
County:	91	Thickness(in)							Minimum	Maximum			0.35	
HWY:	US095	Pavement:		H1:	3.6				100,000	500,000			0.4	
		Base:		H2:	8.4				10,000	100,000			0.4	
		Subbase:		H3:	18				5,000	100,000			0.45	Absolute
		Subgrade:		H4:	244.8				9,200					Dpth
	Load	Measured	Deflection	in	(mils):				Moduli Values in (ksi):					to
Station	(lbs)	R1	R2	R3	R4	R5	R6	R7	E1	E2	E3	E4	ERR/	Bedrock
388.4	10,959	29.56	25.98	23.07	18.25	14.55	9.26	4.13	463	100	6.9	4.6	6.6	300
388.5	10,979	24.96	20.17	17.12	13.14	10.16	6.28	2.96	500	100	5.0	8.7	4.6	300
388.6	11,098	23.37	19.15	16.14	12.25	9.67	6.17	3.15	500	78	15.4	6.5	7.1	300
388.7	10,971	16.78	12.97	10.72	8.11	6.81	5.00	2.85	500	100	26.5	8.8	4.9	300
388.8	10,697	38.33	30.84	25.48	18.20	13.27	7.89	3.57	500	38	5.0	5.5	6.5	215.8
388.9	10,769	21.70	15.68	12.25	8.37	6.08	3.95	2.37	500	59	12.0	11.8	5.0	110.48
389	7,936	12.04	9.29	7.55	5.43	4.13	2.88	1.70	500	100	16.5	12.1	5.3	267.06
389	11,082	15.94	12.31	10.04	7.42	5.79	4.09	2.45	500	100	26.6	10.6	5.6	300
389.1	10,975	23.09	17.57	14.21	10.22	7.57	5.15	2.70	500	48	20.8	7.7	6.8	263.46
389.2	10,979	20.28	16.29	13.29	9.85	7.72	5.56	3.14	500	100	13.6	8.6	4.6	300
389.3	10,931	14.85	11.79	9.75	7.14	5.46	3.69	2.19	500	100	29.7	10.7	7.7	300
389.4	10,900	17.60	14.02	11.67	8.63	6.68	4.46	2.24	500	100	16.4	10.2	5.8	300
389.5	10,963	17.33	13.48	11.14	8.37	6.63	4.75	2.76	500	100	16.9	10.6	6.3	300
389.6	10,927	15.97	12.12	10.10	7.68	6.13	4.30	2.42	500	100	19.4	11.8	6.7	300
389.7	11,059	11.60	7.72	5.89	4.12	3.34	2.56	1.42	500	100	54.1	18.0	5.6	152.32
389.8	10,935	11.69	8.31	6.73	5.27	4.57	3.79	2.72	500	100	100.0	9.8	5.5	300
389.9	10,872	19.85	14.93	11.93	8.75	6.56	4.35	2.67	500	61	21.2	9.5	6.2	300
390	7,741	14.61	10.68	8.46	5.71	4.08	2.36	1.12	500	61	12.8	12.8	7.4	97.87
390	10,848	18.35	13.60	10.86	7.75	5.46	3.56	1.67	500	98	11.4	13.5	4.3	219.99
390.1	10,701	20.39	14.81	11.51	8.47	6.58	5.22	2.85	500	48	29.4	8.3	4.9	300
390.2	10,836	21.89	17.55	15.39	12.07	9.59	6.64	3.21	500	100	11.3	7.2	4.3	300
390.3	10,657	32.27	25.80	21.52	16.84	12.66	8.26	3.26	500	69	5.0	5.8	3.7	300
390.4	10,685	23.09	18.48	15.33	12.47	10.12	7.39	3.95	500	100	8.3	7.1	5.0	300
390.5	10,804	15.31	11.13	8.80	6.35	4.63	3.59	1.29	500	100	23.1	13.5	5.4	293.52
390.6	10,935	12.77	8.67	6.61	4.76	3.52	2.30	0.95	500	100	30.8	19.4	5.3	279.16
390.7	10,717	30.28	24.62	20.59	15.25	11.35	6.61	3.03	500	55	6.5	6.4	7.0	300
390.8	10,375	42.63	32.06	24.54	16.31	11.29	6.57	3.21	500	12	7.9	5.8	7.3	84.35
390.9	10,657	27.13	19.94	15.51	10.41	7.19	3.76	1.27	500	40	7.9	11.1	8.0	92.55
391	7,650	23.79	19.29	15.68	11.37	8.61	5.13	2.42	500	52	5.0	6.5	6.3	300
391	10,769	31.68	25.94	21.45	15.97	12.39	7.64	3.65	500	67	5.0	6.2	5.7	300
Mean:		22.00	16.98	13.84	10.19	7.73	5.03	2.48	499	78	17.0	9.8	5.7	274.84
Std. Dev:		7.19	6.04	5.07	3.80	2.86	1.73	0.83	6	26	16.4	3.7	1.3	197.73
Var Coeff(%):		32.69	35.58	36.67	37.33	36.97	34.40	33.62	1	34	96.6	37.5	23.4	71.94

Figure 16. MODULUS Output File, First Run

MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)

District:	1					MODULI RANGE(psi)	Ratio Values
County:	91	Thickness(in)				Minimum Maximum	0.35
HWY:	US095	Pavement:	H1:	3.6		100,000 800,000	0.4
		Base:	H2:	8.4		20,000 300,000	0.4
		Subbase:	H3:	18		10,000 200,000	0.45
		Subgrade:	H4:	244.8		10,000	

Station	Load (lbs)	Measured Deflection in R1	R2	R3	R4	(mils): R5	R6	R7	Moduli Values in (ksi): E1	E2	E3	E4	ERR/	Absolute to Bedrock
388.4	10,959	29.56	25.98	23.07	18.25	14.55	9.26	4.13	222	128	10.0	4.3	7.2	300
388.5	10,979	24.96	20.17	17.12	13.14	10.16	6.28	2.96	271	46	10.1	5.7	8.8	300
388.6	11,098	23.37	19.15	16.14	12.25	9.67	6.17	3.15	242	57	12.8	4.5	6.3	300
388.7	10,971	16.78	12.97	10.72	8.11	6.81	5.00	2.85	800	132	17.8	9.5	3.9	300
388.8	10,697	38.33	30.84	25.48	18.20	13.27	7.89	3.57	459	25	10.0	4.6	8.6	215.8
388.9	10,769	21.70	15.68	12.25	8.37	6.08	3.95	2.37	800	50	11.8	11.7	4.2	110.48
389	7,936	12.04	9.29	7.55	5.43	4.13	2.88	1.70	800	117	12.5	12.5	3.9	267.06
389	11,082	15.94	12.31	10.04	7.42	5.79	4.09	2.45	800	141	12.9	12.6	3.9	300
389.1	10,975	23.09	17.57	14.21	10.22	7.57	5.15	2.70	800	46	15.3	8.4	4.7	263.46
389.2	10,979	20.28	16.29	13.29	9.85	7.72	5.56	3.14	800	106	10.0	9.1	4.0	300
389.3	10,931	14.85	11.79	9.75	7.14	5.46	3.69	2.19	800	155	13.1	13.1	4.5	300
389.4	10,900	17.60	14.02	11.67	8.63	6.68	4.46	2.24	800	127	10.8	10.8	4.5	300
389.5	10,963	17.33	13.48	11.14	8.37	6.63	4.75	2.76	800	139	11.4	10.8	3.6	300
389.6	10,927	15.97	12.12	10.10	7.68	6.13	4.30	2.42	800	147	14.2	11.4	3.0	300
389.7	11,059	11.60	7.72	5.89	4.12	3.34	2.56	1.42	800	85	53.2	17.7	4.8	152.32
389.8	10,935	11.69	8.31	6.73	5.27	4.57	3.79	2.72	800	119	66.7	11.1	3.5	300
389.9	10,872	19.85	14.93	11.93	8.75	6.56	4.35	2.67	800	83	11.0	11.0	3.6	300
390	7,741	14.61	10.68	8.46	5.71	4.08	2.36	1.12	800	50	12.8	12.8	6.7	97.87
390	10,848	18.35	13.60	10.86	7.75	5.46	3.56	1.67	800	66	13.9	12.9	4.3	219.99
390.1	10,701	20.39	14.81	11.51	8.47	6.58	5.22	2.85	800	48	23.4	8.6	4.0	300
390.2	10,836	21.89	17.55	15.39	12.07	9.59	6.64	3.21	303	27	10.0	3.5	3.7	300
390.3	10,657	32.27	25.80	21.52	16.84	12.66	8.26	3.26	351	35	14.3	4.5	6.9	300
390.4	10,685	23.09	18.48	15.33	12.47	10.12	7.39	3.95	222	50	14.1	3.6	3.0	300
390.5	10,804	15.31	11.13	8.80	6.35	4.63	3.59	1.29	800	56	35.4	11.8	5.3	293.52
390.6	10,935	12.77	8.67	6.61	4.76	3.52	2.30	0.95	800	113	21.2	21.2	3.6	279.16
390.7	10,717	30.28	24.62	20.59	15.25	11.35	6.61	3.03	358	35	12.7	3.6	9.1	300
390.8	10,375	42.63	32.06	24.54	16.31	11.29	6.57	3.21	315	20	10.0	5.1	11.0	84.35
390.9	10,657	27.13	19.94	15.51	10.41	7.19	3.76	1.27	800	28	10.0	10.0	8.0	92.55
391	7,650	23.79	19.29	15.68	11.37	8.61	5.13	2.42	289	25	11.3	4.9	9.3	300
391	10,769	31.68	25.94	21.45	15.97	12.39	7.64	3.65	541	37	10.0	5.4	7.0	300
Mean:		22.00	16.98	13.84	10.19	7.73	5.03	2.48	707	75	16.3	9.5	5.6	274.84
Std.	Dev:	7.19	6.04	5.07	3.80	2.86	1.73	0.83	152	43	11.3	3.8	2.4	197.73

Figure 17. MODULUS Output File, Final Run

The .OUT file is further cleaned up by removing mileposts where the surface moduli hit the upper limit. The reduced file is shown in Figure 18. In this example, the 90th percentile of the values were selected to represent the pavement section. These values are shown at the bottom of the tabulated values in Figure 18. They are: 234 ksi, 26.1 ksi, 10 ksi, and 4 ksi, for the asphalt layer, the base, subbase, and the subgrade, respectively. These values, along with the testing temperature of 91 °F, are used as input values for the WINFLEX program.

Note: For further details, refer to the use of the MODULUS backcalculation program (Reference 6).

MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 5.1)													Ratio Values	
District:	1								MODULI RANGE(psi)				0.35	
County:	91		Thickness(in)						Minimum	Maximum			0.4	
HWY:	US095		Pavement:	H1:		3.6			100,000	800,000			0.4	
			Base:	H2:		8.4			20,000	300,000			0.45	
			Subbase:	H3:		18			10,000	200,000				
			Subgrade:	H4:		244.8			10,000					Absolute
	Load	Measured Deflection in				(mils):			Moduli Values in (ksi):					to
Station	(lbs)	R1	R2	R3	R4	R5	R6	R7	E1	E2	E3	E4	ERR/	Bedrock
388.5	10,979	24.96	20.17	17.12	13.14	10.16	6.28	2.96	271	46	10.1	5.7	8.8	300
388.6	11,098	23.37	19.15	16.14	12.25	9.67	6.17	3.15	242	57	12.8	4.5	6.3	300
390.2	10,836	21.89	17.55	15.39	12.07	9.59	6.64	3.21	303	27	10.0	3.5	3.7	300
390.3	10,657	32.27	25.80	21.52	16.84	12.66	8.26	3.26	351	35	14.3	4.5	6.9	300
390.4	10,685	23.09	18.48	15.33	12.47	10.12	7.39	3.95	222	50	14.1	5.8	3.0	300
390.7	10,717	30.28	24.62	20.59	15.25	11.35	6.61	3.03	358	35	12.7	3.6	9.1	300
391	7,650	23.79	19.29	15.68	11.37	8.61	5.13	2.42	289	25	11.3	4.9	9.3	300
						90th percentile=			234	26.08	10	4		

Figure 18. Final Moduli Values Used in WINFLEX

Step 2: Input Data into WINFLEX

Start WINFLEX and choose New from the File menu, then choose the single-location design from the Select Design Condition screen. First, the pavement data are entered (Figure 19), then the soil parameters (Figure 20), followed by the general data (Figure 21). Two more inputs are needed: failure mode and the associated model. Fatigue was chosen as the controlling distress, and the Asphalt Institute fatigue and rutting models were used to calculate the remaining life.

During FWD testing, it was noticed that the old asphalt was severely cracked and completely deteriorated. This indicated that the old surface layer has lost all of its asphalt properties and should be treated as a gravel layer. This is done by checking the Treat Old AC as Gravel check box in the Pavement Data screen.

Step 3: Running and Output

The past traffic (554,000 ESALs) consumed all of the pavement allowable fatigue life for the old asphalt layer. In this case the remaining life would be zero ESALs, so an overlay is required to resist all the future traffic (5,113,000).

In order to carry the future traffic, the pavement requires an overlay of 6.7 inches. After placing the overlay, the expected fatigue life consumption at the end of the design life (20 years) for the overlay is 0.9962%.

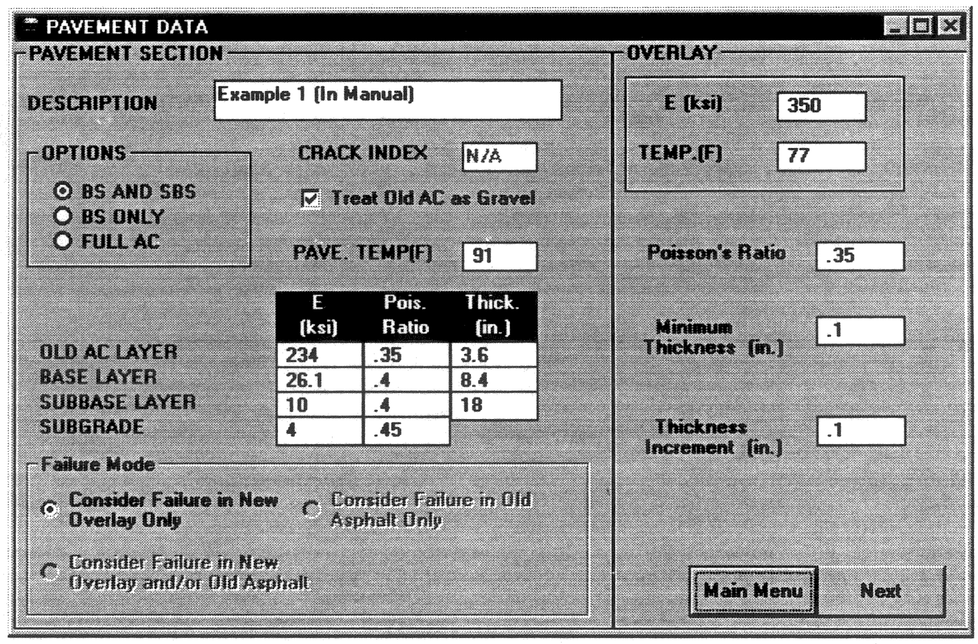


Figure 19. Example 1: Pavement Data

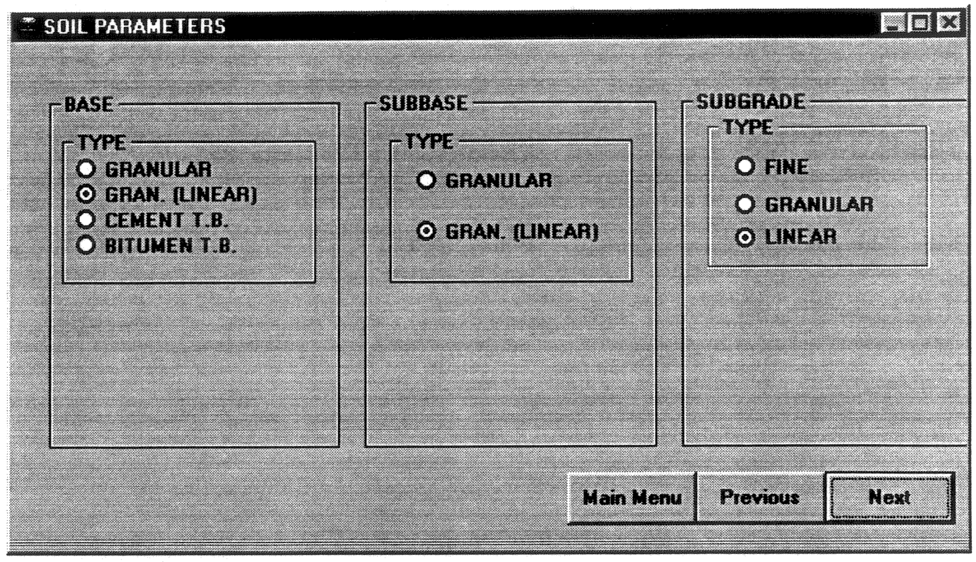


Figure 20. Example 1: Soil Data

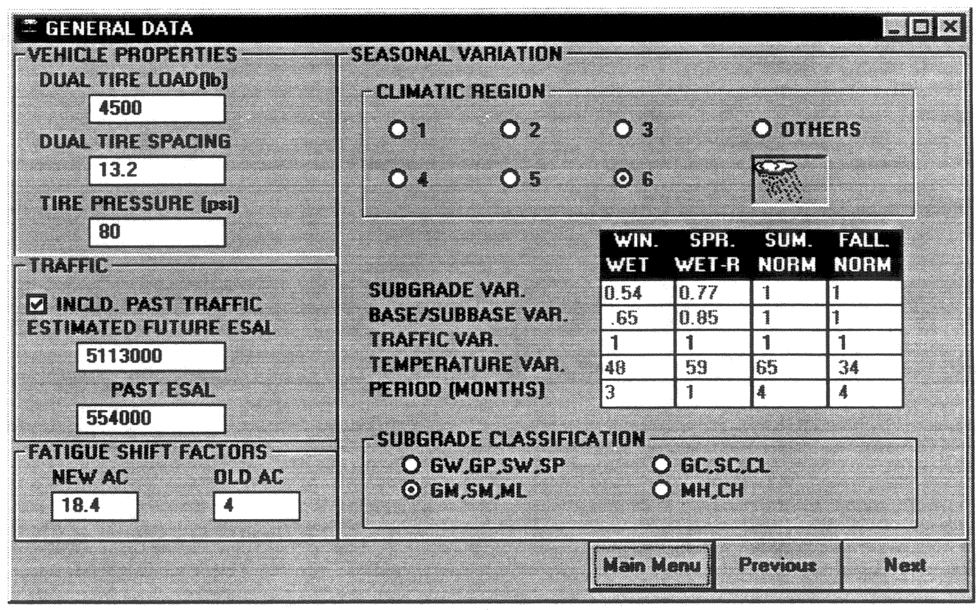


Figure 21. Example 1: General Data

Adding the subgrade rutting (also using the Transportation Road Research Laboratory rutting model to calculate the remaining life) as a controlling distress, the overlay requirement goes up to 6.1. This shows that with this pavement section, subgrade rutting is more dominant.

WINFLEX has a printout feature so that the user can print the detailed results. The printout of the results include:

- a summary of the input data.
- adjusted layer moduli values used for each season.
- the required overlay thickness and the damage level for fatigue and rutting.

- the calculated tensile strain at the bottom of the overlay and the bottom of the existing asphalt layer and the allowable fatigue life (Nf) for each season
- the calculated compressive strain at the top of the subgrade and the allowable rutting life (Nr) for each season.

The print-out of the last run of example 1 is provided in Appendix B.

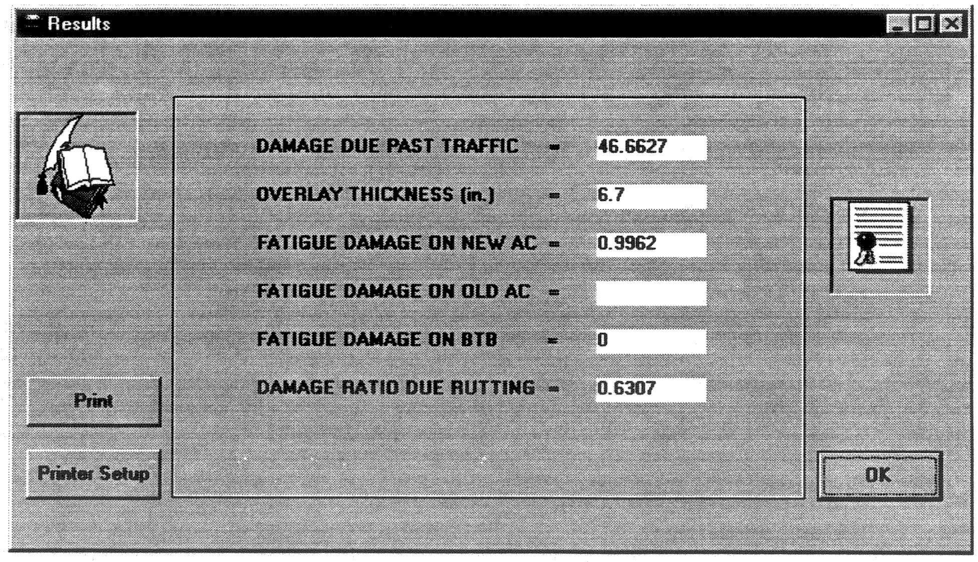


Figure 22. Sample Results for Example 1

Example 2: Multiple-Location Design Case

The same pavement section that was used un example 1, is used here to demonstrate the case where an overlay is designed for each milepost.

Step 1: Create an .ETF file from Backcalculation

Follow the procedures explained in Step 1 in Example 1 to obtain the output of the MODULUS backcalculation software shown in Figure 18. The temperature, milepost, and moduli values of all the layers shown in the output are used to create the .ETF file, *EXAMPLE2.ETF,* as explained earlier in chapter 2.

Step 2: Input Data in WINFLEX

Start WINFLEX and choose New from the File menu then choose the multiple-location design from the Select Design Condition screen. Again, the pavement data are entered first then the soil parameters followed by the general data. The Asphalt Institute fatigue and rutting models were used to calculate the remaining life.

Step 3: Running and Output

After going through the Input screens, choose RunFile from the Result menu. You will then be prompted to enter the .ETF filename. Once you choose your file and click OK, WINFLEX will start the calculations.

After the calculations are done, you will be prompted to save your output. If you do not wish to save your results, just click Cancel.

The summary of the results of running the EXAMPLE2.INP file with the EXAMPLE2.ETF file, provided by the Excel Summary feature in WINFLEX (Figure 12), are shown in Figure 23. You will get a more detailed output in the .FLX file, as explained in Chapter 2.

Fatigue equation = AI
Rutting Equation = AI

Overlay	Dama	Dama2	Dama3	Dama4	Dama22	E1	E2	E3	E4	H1	H2	H3
5.7	0.996	0	0	0.274	8.1313	271	46	10	5.7	3.6	8.4	18
5.3	0.99	0	0	0.429	3.3115	242	57	13	4.5	3.6	8.4	18
6.7	0.983	0	0	0.815	41.632	303	27	10	3.5	3.6	8.4	18
6.1	0.96	0	0	0.419	19.349	351	35	14	4.5	3.6	8.4	18
5.4	0.997	0	0	0.25	5.9333	222	50	14	5.8	3.6	8.4	18
6.1	0.992	0	0	0.702	18.673	358	35	13	3.6	3.6	8.4	18
6.7	0.979	0	0	0.395	53.318	289	25	11	4.9	3.6	8.4	18
5.36	90th percentile											

Figure 23. WINFLEX Output File Considering Fatigue Failure

The final step is to report the designed overlay thickness. In this example, the overlay thickness required to satisfy asphalt fatigue and subgrade rutting is 5.36 inches, based on the 90^{th} percentile value.

Appendix A

References

1) Bayomy, F., Nassar, W. and Al-Kandari, F., "Development of Mechanistic Based Overlay Design System for the State of Idaho." Final Report, Volumes I and II, Research Project No. 95-60-121, National Center for Advanced Transportation Technology, University of Idaho, Moscow, July 1996.
2) Bayomy, F., Al-Kandari, F. and Smith, R., "Mechanistic Based Overlay Design System for Idaho." *Transportation Research Record 1543*, TRB, National Research Council, Washington D.C., 1996, pp. 10-19.
3) Nassar, W., "Analysis and Validation of the Mechantistic-Empirical Overlay Design Procedure Incorporated in FLEXWIN Computer Program." M.S. Thesis, University of Idaho, Moscow, June 1997.
4) Bayomy, F., Al-Kandari, F. and Nassar, W., "Computer Aided Overlay Design System For Flexible Pavements," Proceedings of the 8th International Conference on Asphalt Pavements, Seattle, WA, August 10-14, 1997.
5) Hardcastle, J.H., "Subgrade Resilient Modulus for Idaho Pavements." Idaho Transportation Department, Boise, ID, June 1992.
6) MODULUS 4.0 User Manual, Texas Transportation Institute College Station, TX, 1990.

Appendix B

Example of .ETF file

4	THIS FILE SHOULD BE RUN WITH Example2.inp							
81	388.502	271	46	10.1	5.7	3.6	8.4	18
83	388.6	242	57	12.8	4.5	3.6	8.4	18
85	390.201	303	27	10.0	3.5	3.6	8.4	18
81	390.3	351	35	14.3	4.5	3.6	8.4	18
90	390.4	222	50	14.1	5.8	3.6	8.4	18
82	390.7	358	35	12.7	3.6	3.6	8.4	18
85	391	289	25	11.3	4.9	3.6	8.4	18

Example of Single-Location Output

8/8/97 11:17:25 AM

PAGE 1/2

DESCRIPTION : Example 1 (In Manual)

1. SUMMARY OF INPUT DATA

1.1 TRAFFIC DATA

DESIGN DUAL TIRE LOAD	= 4500
DESIGN DUAL TIRE SPACING	= 13.2
TIRE PRESSURE (psi)	= 80
DESIGN FUTURE TRAFFIC (ESALs)	= 5113000
ESTIMATED PAST TRAFFIC (ESALs)	= 554000
FATIGUE SHIFT FACTOR FOR NEW ASPHALT	= 18.4
FATIGUE SHIFT FACTOR FOR OLD ASPHALT	= 4

1.2 SEASONAL VARIATION DATA

	WINTER	SPRING	SUMMER	FALL
SUBGRADE VARIATION	0.54	0.77	1.00	1.00
BASE/SBASE VARIATION	0.65	0.85	1.00	1.00
TRAFFIC VARIATION	1.00	1.00	1.00	1.00
TEMPERATURE VARIATION	48.00	59.00	65.00	34.00
PERIOD (MONTHS)	3.00	1.00	4.00	4.00

1.3 PAVEMENT DATA

CRACK INDEX = 0
CLIMATIC ZONE :
TEMPERATURE AT FWD TEST = 91
OLD AC BITUMEN VOLUME (Vb) % = 11
OLD AC AIR VOLUME (Va) % = 5

	MODULUS (ksi)	POISSON RATIO	THICKNESS (in.)
OLD AC LAYER	0234.00	0.35	03.60
BASE LAYER	0026.10	0.40	08.40
SUBBASE LAYER	0010.00	0.40	18.00
SUBGRADE	0004.00	0.45	SEMI-INFINITE

SUBGRADE TYPE : LINEAR

BASE TYPE : LINEAR
SUB-BASE TYPE : LINEAR

OVERLAY MODULUS(ksi) = 350 AT TEMPERATURE (F) = 77
POISSON RATIO = 0.35
MINIMUM THICKNESS = 0.1
BITUMEN VOLUME (Vb) % = 11 AIR VOLUME (Va) % = 5

2. SUMMARY OF RESULTS

2.1 EVALUATION OF LAYER MDDULI VALUES FOR EACH SEASON

SEASON	OVERLAY	OLD AC	BASE	SUBBASE	SUBGRADE
1	0350.00	0070.00	0017.00	0008.50	0003.08
2	0350.00	0070.00	0022.20	0010.00	0004.00
3	0350.00	0070.00	0026.10	0010.00	0004.00
4	0350.00	0070.00	0026.10	0006.50	0002.16

2.2 OVERLAY THICKNESS AND DAMAGE ANALYSIS

The fatigue model used was 'Asphalt Institute'
The Rutting model used was 'Asphalt Institute'

FINAL OVERLAY THICKNESS = 06.70
FATIGUE DAMAGE DUE PAST TRAFFIC =
FATIGUE DAMAGE ON OVERLAY =
FATIGUE DAMAGE ON OLD AC =
RUTTUNIG DAMAGE =

SEASON 1

OVERLAY (B)	06.69	RAD.	STR.	MICRO	0161.33	Nf	4304910
OLD AC (B)	36.72	RAD.	STR.	MICRO	-0298.08	Nf	8309078
SUBGRADE(T)	06.69	COMP.	STR.	MICRO	0150.97	Nd	5356318

SEASON 2

OVERLAY (B)	36.72	RAD.	STR.	MICRO	-0247.88	Nf	18971390
OLD AC (B)	06.69	RAD.	STR.	MICRO	0146.38	Nf	5929326
SUBGRADE(T)	36.72	COMP.	STR.	MICRO	-0242.08	Nd	21092030

SEASON 3

OVERLAY (B)	06.69	RAD.	STR.	MICRO	0152.96	Nf	5129665
OLD AC (B)	36.72	RAD.	STR.	MICRO	-0340.79	Nf	4562197

Example of .FLX file

```
INPUT FILE : D:\waleed\Myflexolay\flex with dll\mexample.inp

DESCRIPTION : fm3

1. SUMMARY OF INPUT DATA
------------------------

1.1  TRAFFIC DATA
-----------------
DESIGN DUAL TIRE LOAD              = 4500
DESIGN DUAL TIRE SPACING           = 13.2
TIRE PRESSURE (psi)                = 80
DESIGN FUTURE TRAFFIC (ESALs)      = 13000000
ESTIMATED PAST TRAFFIC (ESALs)     = 100000
FATIGUE SHIFT FACTOR FOR NEW ASPHALT  = 18.4
FATIGUE SHIFT FACTOR FOR OLD ASPHALT  = 4

1.2  SEASONAL VARIATION DATA
----------------------------
                  WINTER  SPRING  SUMMER  FALL
SUBGRADE VARIATION      12.63   0.40   1.00   1.00
BASE/SBASE VARIATION    1.00   0.65   1.00   1.00
TRAFFIC VARIATION       1.00   1.00   1.00   1.00
TEMPERATURE VARIATION  33.00  53.00  62.00  36.00
PERIOD (MONTHS)         3.00   1.00   4.00   4.00

1.3  PAVEMENT DATA
------------------
CRACK INDEX =               2
CLIMATIC ZONE :
TEMPERATURE AT FWD TEST     =  0
OLD AC BITUMEN VOLUME (Vb) % =  11
OLD AC AIR VOLUME (Va) %    =  5

             POISSON   THICKNESS
             RATIO     (in.)
OLD AC LAYER     0.35    00.00
BASE LAYER       0.40    00.00
SUBBASE LAYER    0.40    00.00
SUBGRADE         0.45    SEMI-INFINITE
```

SUBGRADE TYPE : LINEAR

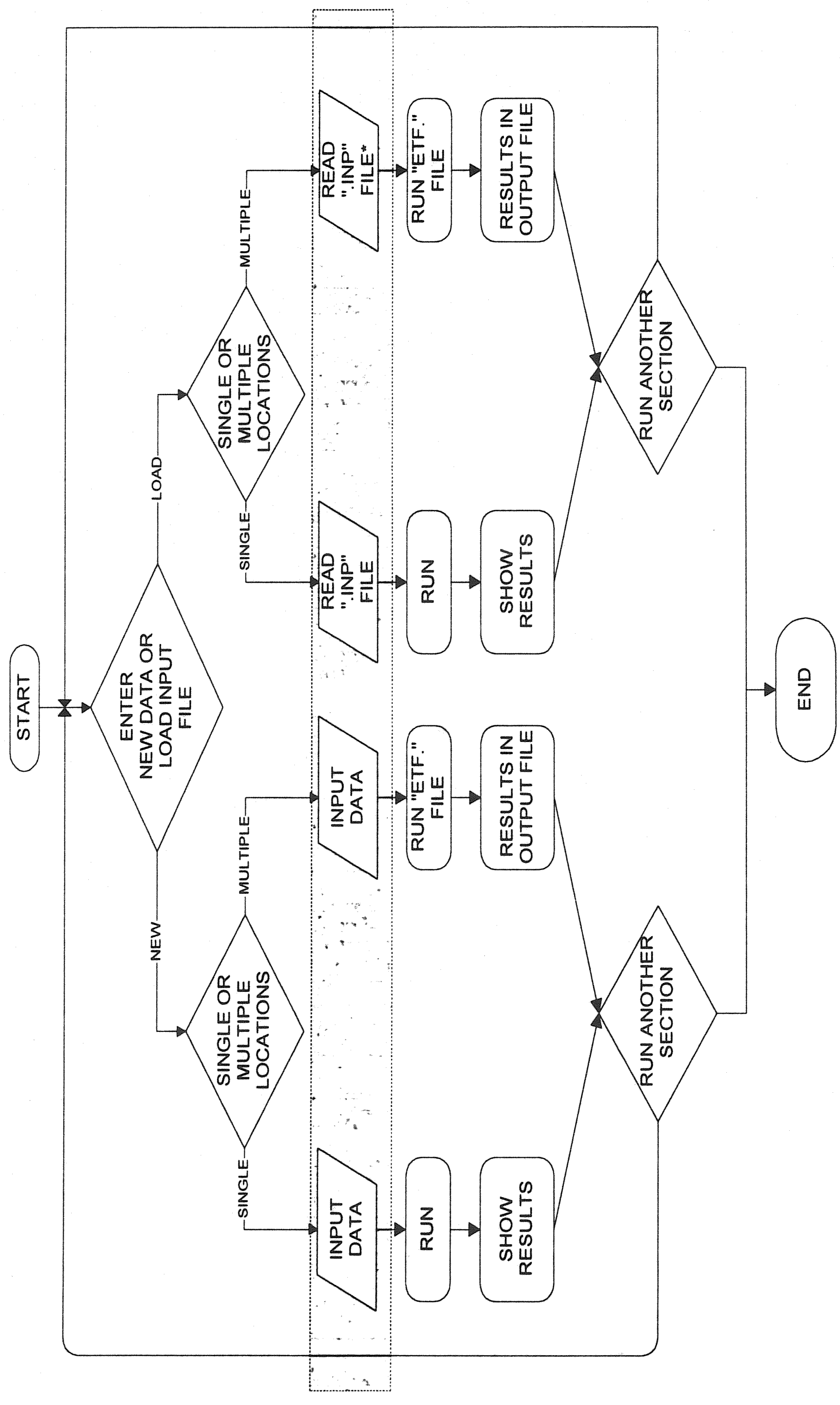
BASE TYPE : LINEAR
SUB-BASE TYPE : LINEAR

OVERLAY MODULUS(ksi) = 350 AT TEMPERATURE (F) = 77
POISSON RATIO = 0.35
MINIMUM THICKNESS = 1
BITUMEN VOLUME (Vb) % = 11 AIR VOLUME (Va) % = 5
ETF FILE : mult-example.etf
THIS FILE SHOULD BE RUN WITH Example2.inp

CASE	MILE POST	TEMPERATURE	E1	E2	E3	E4	OVERLAY	DAMA1	DAMA2	DAMA3	DAMA4	DAMA22	H1	H2	H3
1	388.502	81	271	46	10.1	5.7	7	0.027	0.9516	0	0	0.1127	3.6	8.4	18
2	388.6	83	242	57	12.8	4.5	6.5	0.032	0.8704	0	0	0.0712	3.6	8.4	18
3	390.201	85	303	27	10	3.5	9	0.020	0.8752	0	0	0.2636	3.6	8.4	18
4	390.3	81	351	35	14.3	4.5	7	0.014	0.9085	0	0	0.1346	3.6	8.4	18
5	390.4	90	222	50	14.1	5.8	7	0.039	0.8933	0	0	0.1022	3.6	8.4	18
6	390.7	82	358	35	12.7	3.6	7	0.013	0.9548	0	0	0.1353	3.6	8.4	18
7	391	85	289	25	11.3	4.9	9	0.022	0.9298	0	0	0.3044	3.6	8.4	18

DAMA1 = FATIGUE DAMAGE ON OVERLAY
DAMA2 = FATIGUE DAMAGE ON OLD AC
DAMA3 = FATIGUE DAMAGE ON BTB
DAMA4 = RUTTING DAMAGE
DAMA22 = FATIGUE DAMAGE DUE TO PAST TRAFFIC
The fatigue model used was 'ILLINOIS DOT'
The Rutting model used was 'Asphalt Institute'

Appendix C



* The ".INP" file for the multiple loaction exectution does not contain layer moduli values and the test temperature

Figure C-1 Visual Basic Procedures Flowchart

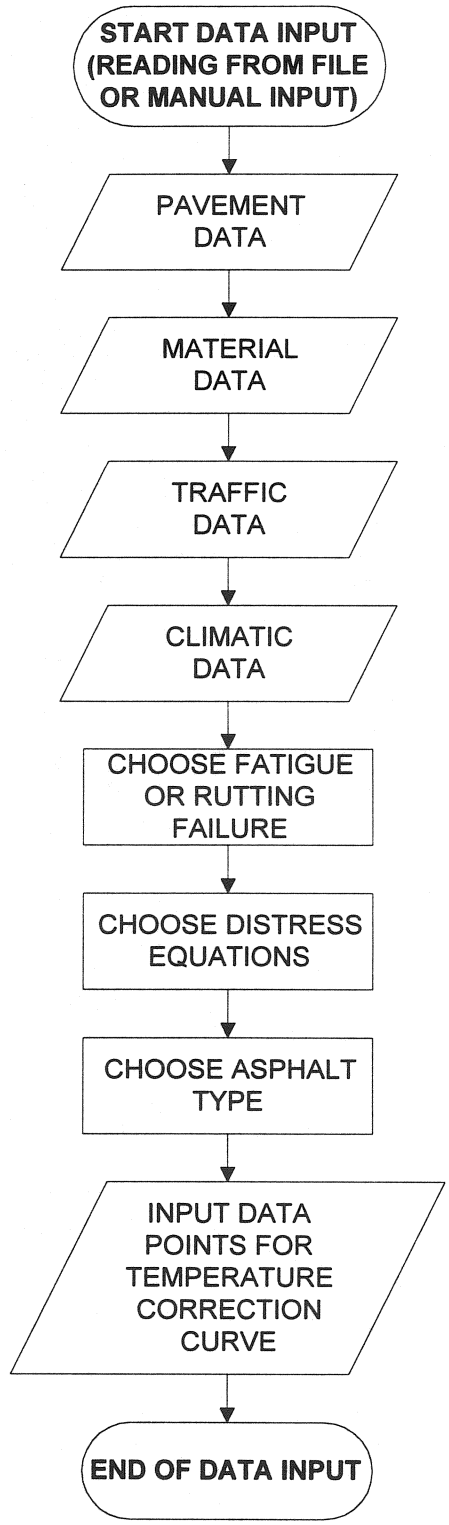


Figure C-2 Input Data

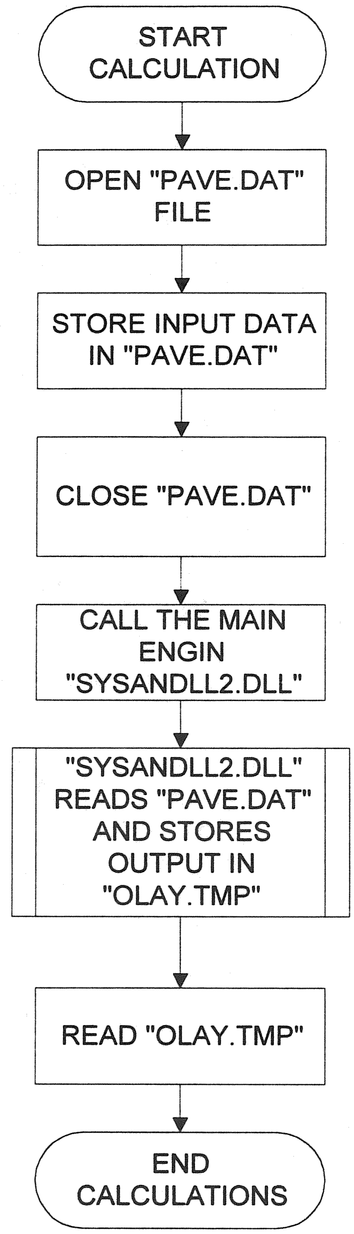


Figure C-3 Run Procedure

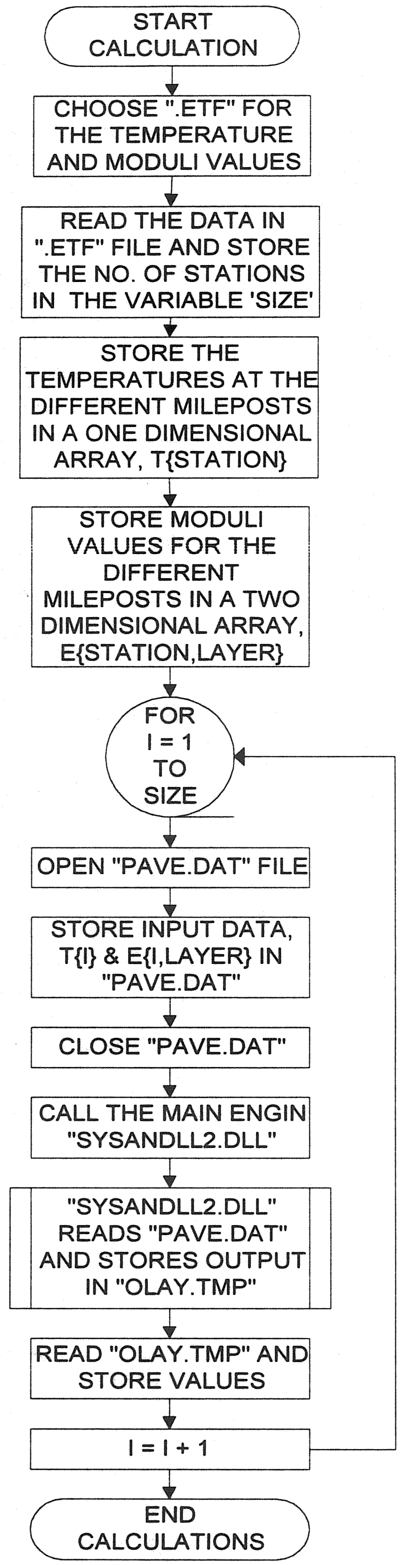


Figure C-4 Runfile Procedure

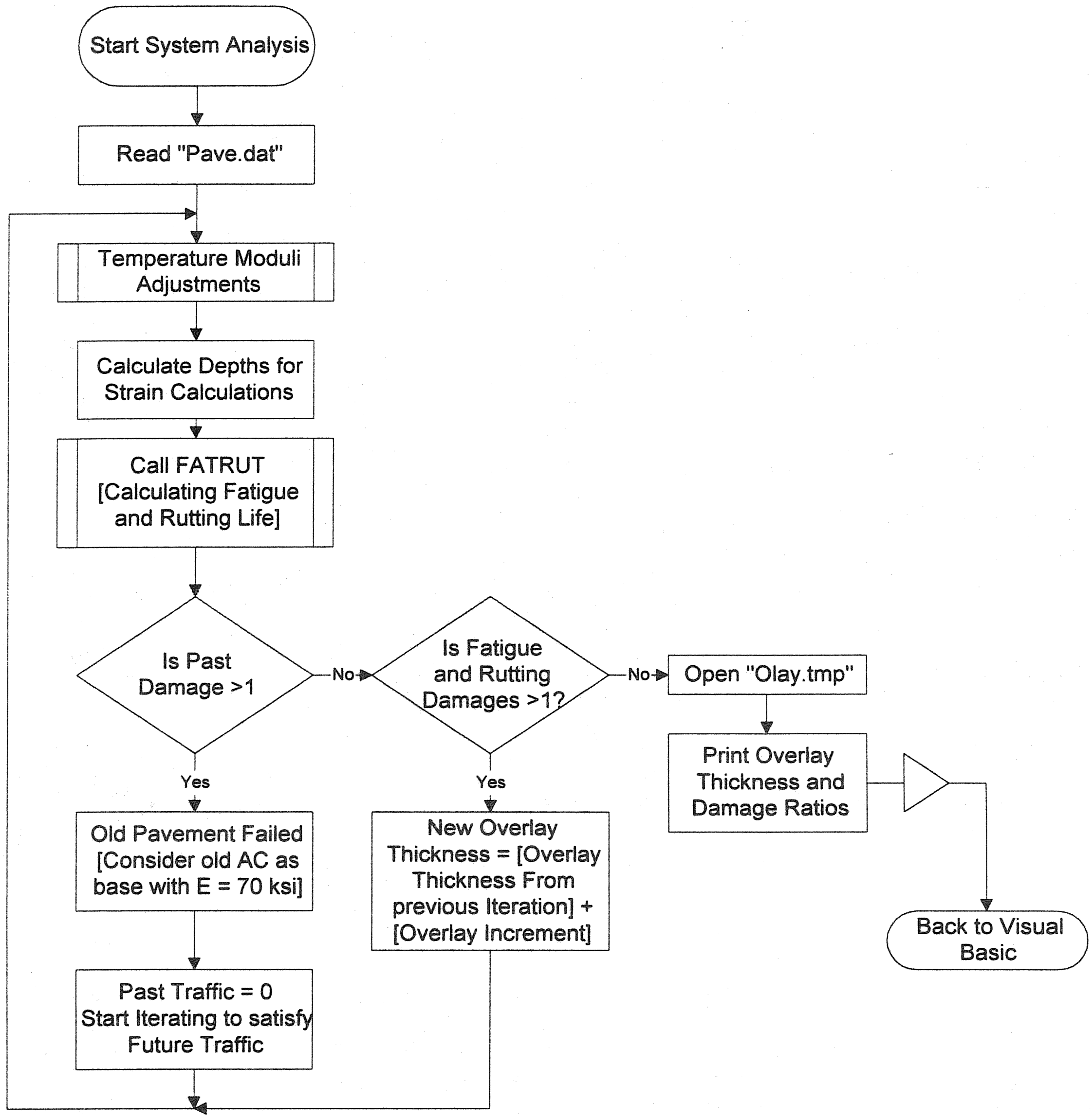


Figure C-5 Main Flowchart In SYSANDDLL2

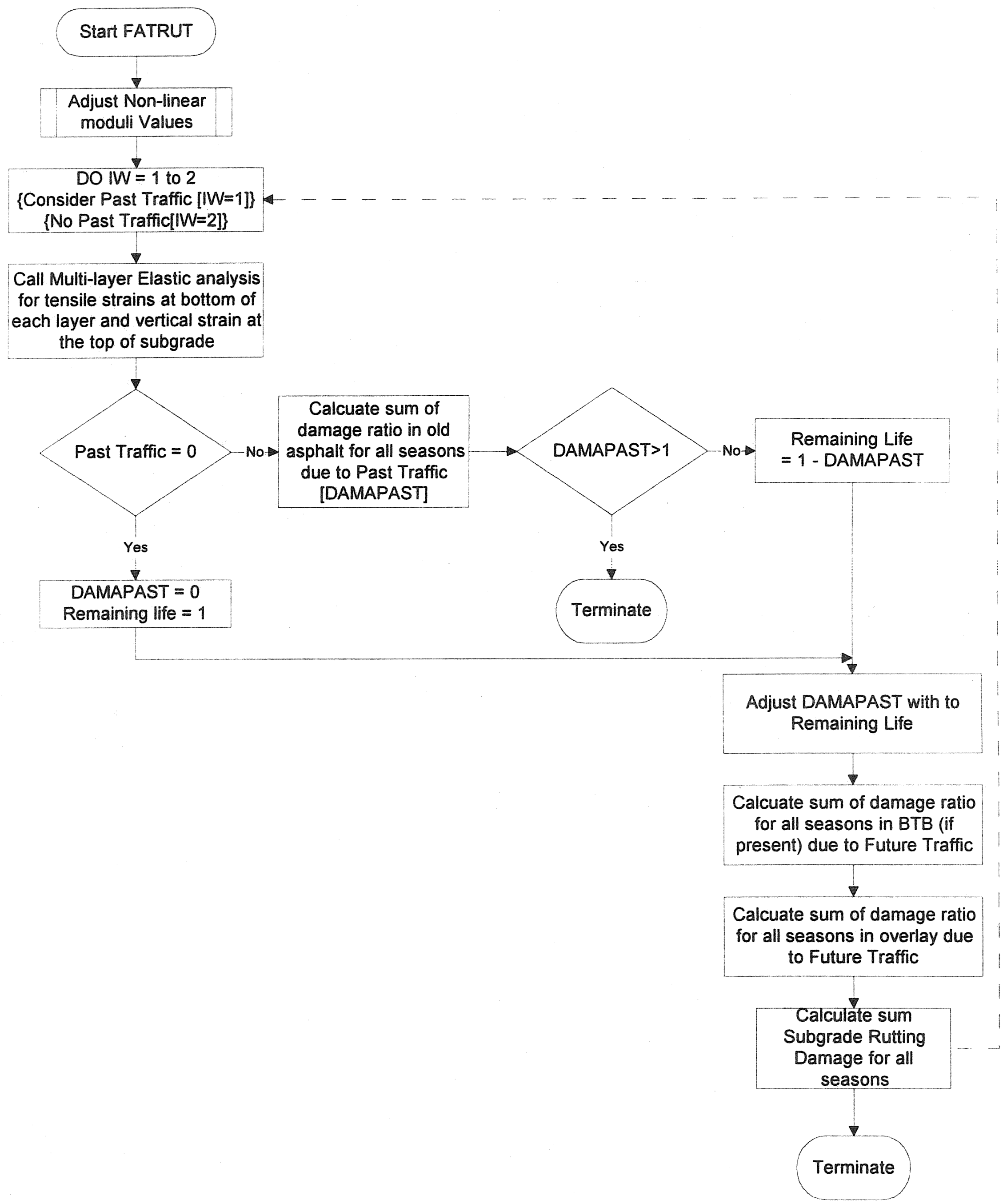


Figure C-6 Fatigue Life, Rutting Life and Damage Calculation Procedure

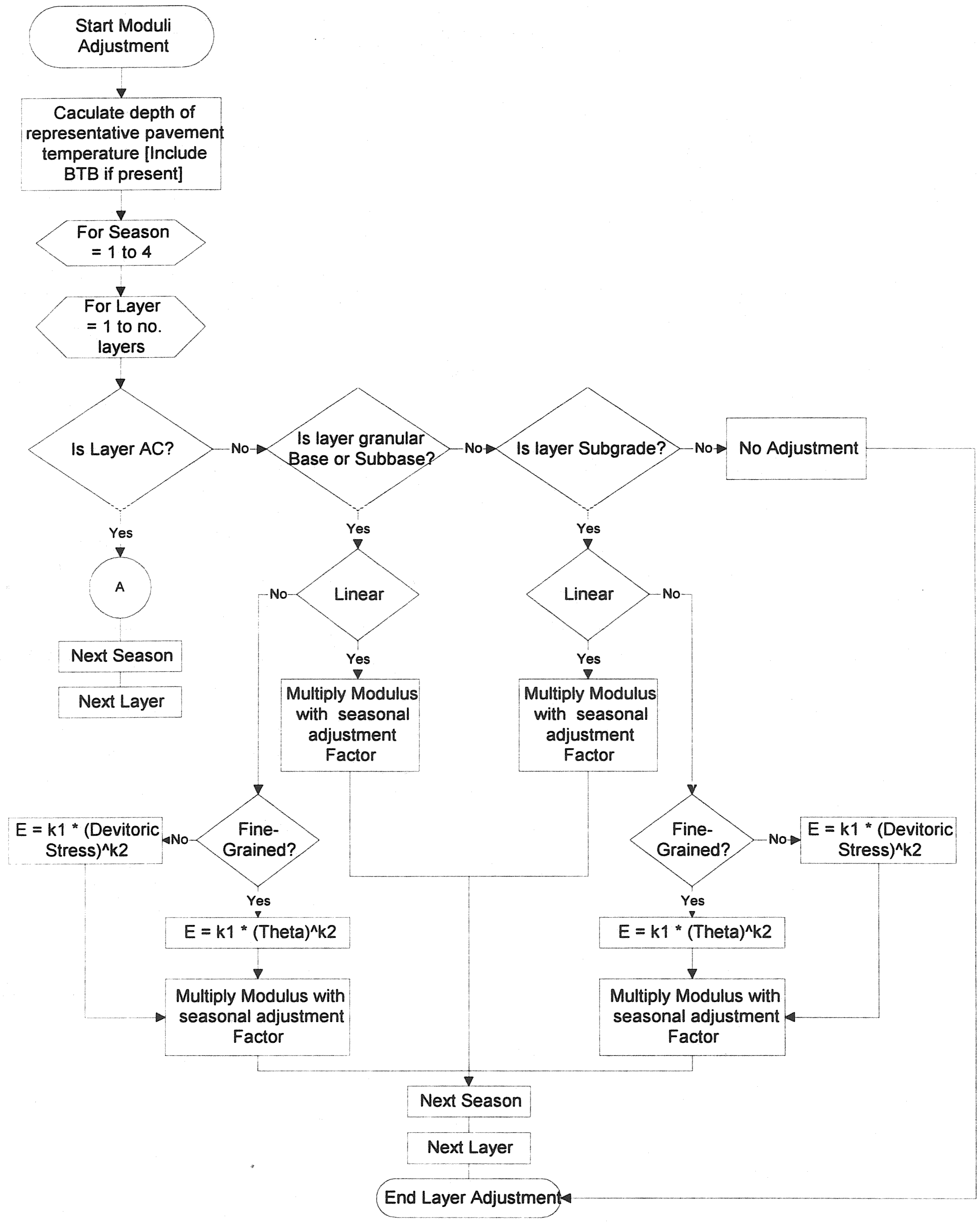


Figure C-7 Temperature Adjustment Procedure For Layer Moduli

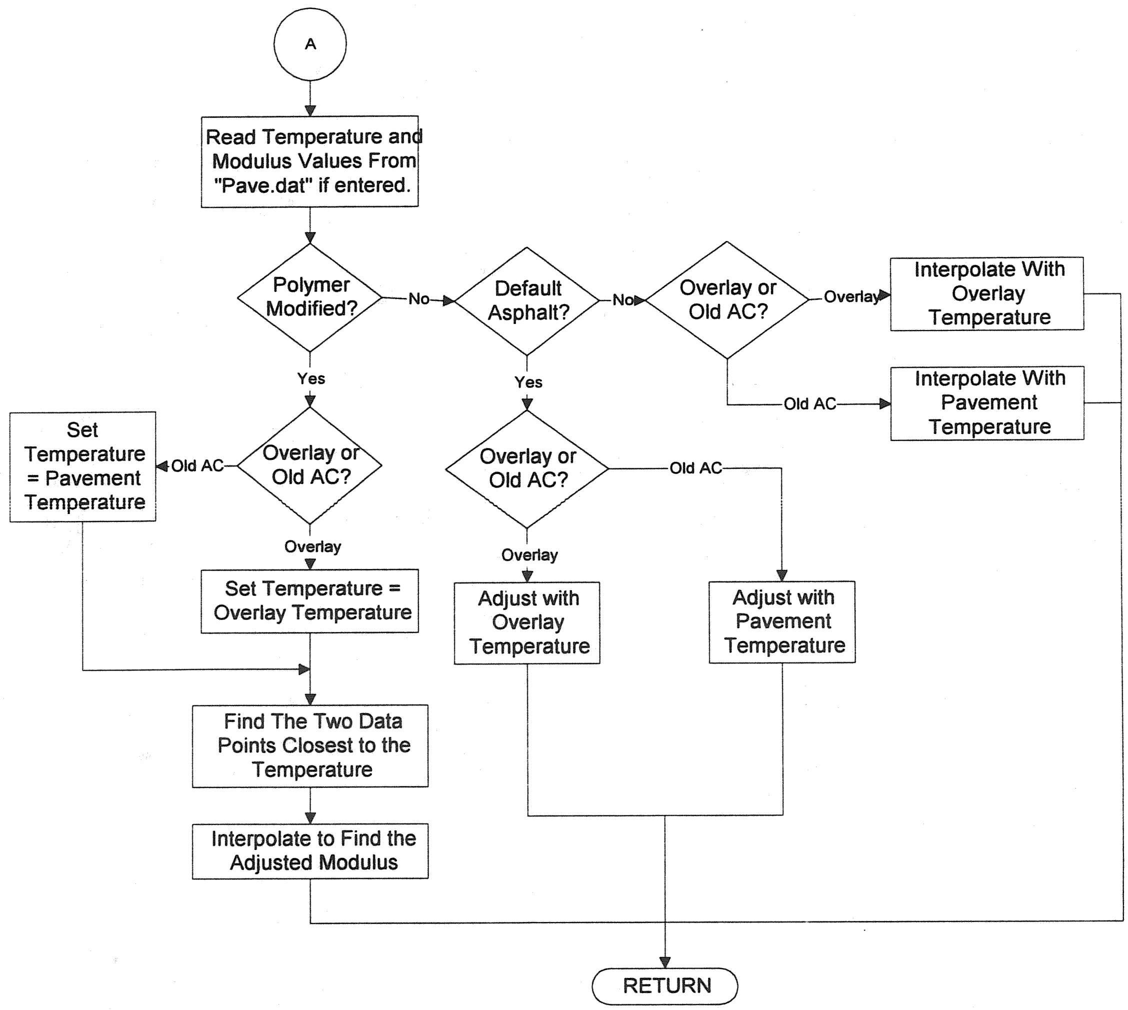


Figure C-8 Temperature Adjustment For Asphalt layers Moduli

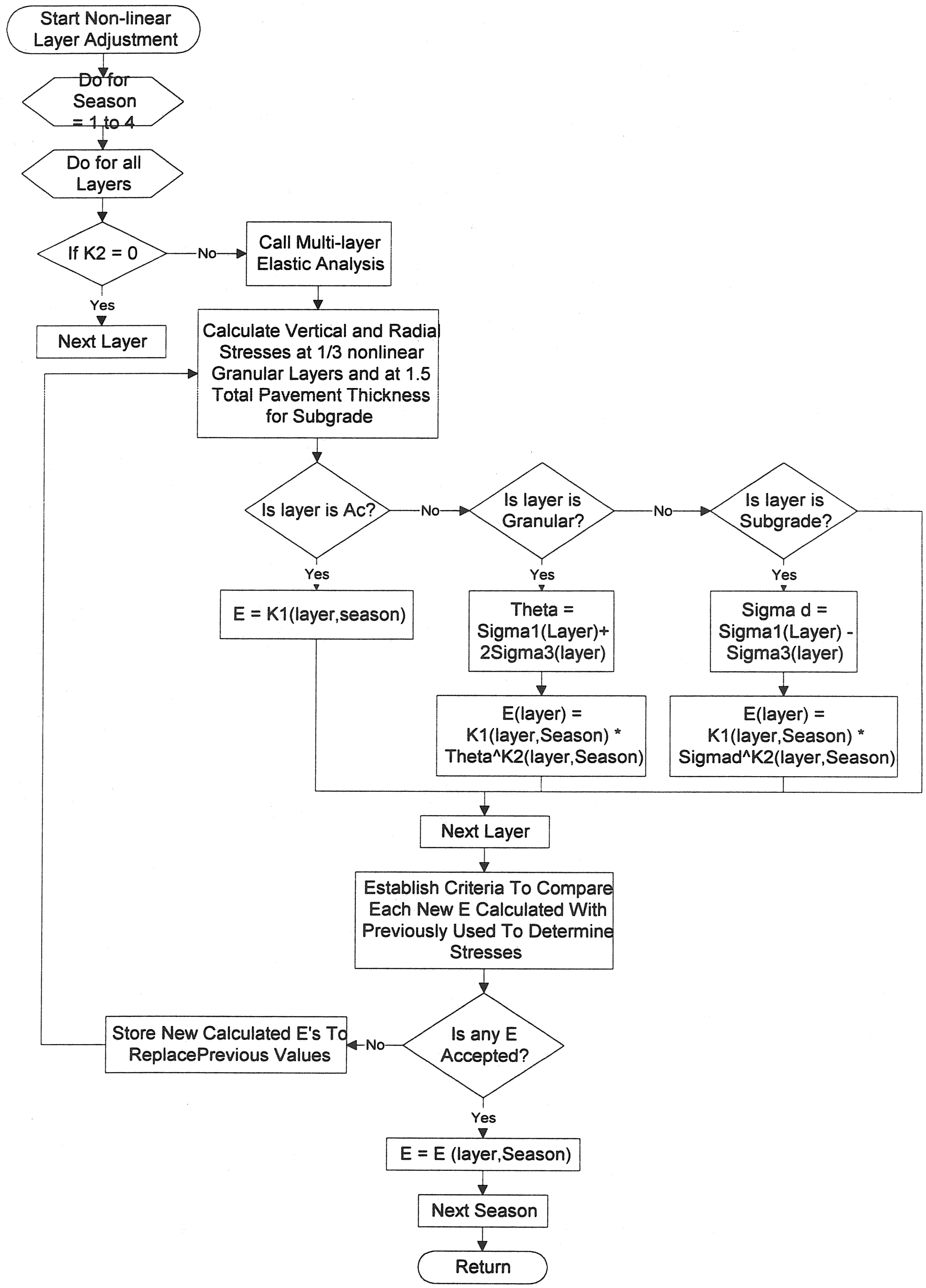


Figure C-9 Moduli Adjustment for Non-Linear Layers

Appendix D

Getting Help

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